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THE DEVELOPMENT OF A LABORATORY
TECHNIQUE FOR
MODEL CONSTRUCTION

WILLIAM MANVILLE JOHNSON, JR.
AND DANIEL NELSON SHOCKEY

THESIS
J64

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THE DEVELOPMENT OF A LABORATORY TECHNIQUE
FOR MODEL CONSTRUCTION

Submitted to the Faculty of
RENSSELAER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements
for the degree of
MASTER OF CIVIL ENGINEERING

By

WILLIAM MANVILLE JOHNSON JR.
DANIEL NELSON SHOCKEY

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THE UNIVERSITY OF CHICAGO
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BY
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1954

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INTRODUCTION

Present day structural design is based upon theory composed of numerous assumptions, some of which have been proved rigidly by experimental data while others have been shown to be adequate only so long as a large enough safety factor is introduced. The strength and stability of the majority of our structures which have been built in the last thirty years attest the overall adequacy of the theory being used. However, as stated above, this theory is padded in numerous places with high safety factors to insure adequacy in instances where experimental data is lacking. Of course, information which is lacking could be obtained by trial and error -- building a structure, loading it, and observing whether or not the structure supported the loads to which it was subjected. If a person lived long enough and had unlimited resources, he might obtain some very important information in this way. However, as has been done in the past and as will probably be done in the future, designers have attempted to make models of the structures they wished to investigate and, by subjecting those models to loads which simulated the actual loading, learn something about the action of the prototype. Model analysis has proved very useful in some instances.

In the field of rigid frames, for example, little is known about the stresses at the knees. Practically all the information we have at this time came from the results of some full and quarter scale tests conducted several years ago by the U. S. Bureau of Standards, Lehigh and Columbia Universities,

INTRODUCTION

Present day experimental design is based upon the assumption of numerous assumptions, some of which have been questioned by experimental data while others have been shown to be impossible only so far as a large enough sample is concerned. The strength and stability of the subject of our experiments which have been built in our last thirty years around the overall assumption of the theory of the mind, however, is still intact, this theory is based on numerous lines of evidence which lead to lower complexity in individual cases. The fact is that, of course, information which is lacking could be obtained by trial and error - building a structure, loading it, and observing whether or not the structure supported the loads to which it was subjected. If a person lived long enough and had unlimited resources, he might obtain some very important information in this way. However, as has been done in the past and as will probably be done in the future, scientists have attempted to learn details of the processes that relate to investigation and, by reflection, learn details of loads which simulated the actual loading, learn something about the action of the prototype. Such analysis has proven very useful in some instances.

In the field of field trials, for example, little is known about the stresses of the human body. Presumably all the information we have at this time came from the results of tests and perhaps some tests conducted several years ago by the D. E. Bureau of Standards, Johns and Columbia Universities,

and the University of Illinois. These tests were very expensive, and are not likely to be repeated for checking purposes in the near future. The results of these tests disagreed radically with the stresses predicted by theory. Although a new theory was evolved, to date it has not been checked. The small scale testing that has been done up to this time has not yielded, in general, satisfactory results.

In an effort to help solve this problem, E. J. Scullen designed and constructed at Rensselaer Polytechnic Institute in 1950, as a master's thesis, a model testing frame which could accommodate intermediate scale models (approximately one twenty-fifth to one fifteenth scale.) It was hoped that by testing intermediate scale models, accurate information could be obtained at much less expense than by testing large scale models.

The object of our thesis, then, was to develop a technique for constructing the intermediate scale models. The prime requirement of any technique would be to produce a model which could be expected to simulate the action of its prototype. The technique should be inexpensive. It should be simple, so that master craftsmen are not required to build the model. The technique should facilitate rapid construction of a model. Last of all, the technique should be flexible, lending itself to the fabrication of models of varied shapes.

In the attainment of the object as presented above, the authors constructed many different models and tested these models by various means to determine their suitability for model analysis.

I. CONSIDERATION OF MATERIALS TO BE USED

The problem of building a suitable model for laboratory analysis is a matter not only of the techniques and methods that might be used, but also a matter of what material should be used. Therefore, it is necessary first of all to look at the various materials readily available, and from these, to pick one or two that seem to possess the greatest possibilities for success.

Those materials which seemed to us to offer the best possibilities were: aluminum, steel, plastic, and wood.

An understanding of the problem of using the loading frame with the high loads which it will be desirable to apply will bring to mind a question about the feasibility of using wood and plastic. Wood, of course, is readily available, but the difficulty of fabricating suitable models such that reasonable values could be predicted for their prototypes is a major problem. Also, knowing that eventually it will be desirable to build welded structures, the making of suitable joints with wood that would resemble welded joints presents a problem of questionable solution. The possibility of using plastic is equally as difficult as using wood, not only because of the problem of putting joints together and the low loads plastics are capable of carrying, but of great importance is the fact that residual, stress free models are very difficult to make.

This then brings us to aluminum and steel. These two metals were chosen in preference to other metals due to the

great deal of information that is known about them, such that the problem of making models might be simplified by using techniques already recognized as acceptable. It was decided to use aluminum first, primarily because of a ready supply on hand, along with the fact that the equipment available was best suited for handling that material. The most recognized characteristics of aluminum are its light weight, resistance to corrosion, and high strength, which make it highly desirable for this work. However, there are several properties of aluminum which tend to hinder the possibility of success. These are: (1) the fact that the melting point of aluminum is very close to the welding temperature such that great care is needed to avoid melting the parent material while welding, and; (2) the coefficient of thermal expansion of aluminum is slightly more than twice that of cast iron or steel with the resulting effect that care must be taken to consider expansion and to control it carefully in order to avoid distortion. Secondly, we decided to try steel as a material for a possible second method even if aluminum should work out. This would prove to be very helpful, if successful, since with the higher strength of steel it would be possible to build models which would be capable of carrying the full load of the loading frame.

Thus, with this in mind we started with aluminum as our first material and proceeded as the following pages indicate.

II. ALUMINUM MODULUS CHECK

In the fabrication of models from aluminum by brazing, soldering, or welding it is necessary to heat the aluminum, the temperature required depending upon the method used. Aluminum alloys which derive their strength from alloying and subsequent tempering* are annealed by reheating (if the reheating temperature is high enough) and lose their strength. Aluminum alloys which derive their strength from alloying alone are not appreciably changed by heating them to temperatures below their melting points. Of the alloys tested, 61ST6 is one of the former, while 52SO is one of the latter. We were interested in finding out what happened to these alloys, with respect to their structural strength, specifically their moduli of elasticity, when they were heated to temperatures required for brazing, soldering, or welding. As stated in The Aluminum Company of America's literature, "Alcoa Aluminum and Its Alloys," and "Welding and Brazing Alcoa Aluminum," the results of heating these alloys could be determined for each case only by individual tests. We, therefore, elected to test various heated and unheated samples by using electric strain gage equipment.

A. Electric Strain Gage Equipment**

1. General

The electric strain gage equipment used was

* Engineering Physical Metallurgy (Chapter 4) - Meyer

** For a detailed description and for operation procedure, see Baldwin instruction book, bulletin 312, entitled "Type L Portable Strain Indicator."

composed of, essentially, bonded wire strain gages, type SR-4, and an electric indicating device for measuring strains, in micro-inches, produced in those strain gages by some type of loading applied to the material upon which the gages were mounted. The indicating device, Baldwin Type L, indicates strains resulting from the loading by measuring the change in electrical resistance produced in the bonded gages.

Leading to the indicator are two sets of wires, one set from the active gage and one set from the compensating gage. The active gage is mounted on the test piece or model which is to be loaded; the compensating gage is mounted on a piece of the same material as that on which the active gage is mounted, is placed near the active gage, but is not loaded. The purpose of the compensating gage is to correct the strain reading for temperature prevailing in the vicinity of the active gage.

2. Operating Procedure

- a. Check calibration of indicating device if equipment is being used for the first time.*
- b. Check batteries; if the pointer remains in the red part of the dial, new batteries are needed.
- c. Connect leads from compensating and active gages to their respective terminals.

* See Calibration Check Procedure below.

- d. Turn battery switch to ON position, and allow 10 seconds for tube warm-up.
- e. Set the correct value of gage factor, as supplied by the gage manufacturer, on the gage factor dial.
- f. Bring the pointer to zero, and read the indicator dial. This is the zero reading.
- g. Load the test piece, bring the pointer to zero, and read the indicator dial. This is the loaded reading. The difference between the zero reading and the loaded reading is the strain produced in the test piece by the load, in micro-inches.

For best results, use hot soldered joints in connecting lead wires to gages, and make both lead wires to any one gage the same length. Also, place the compensating gage as near as possible to the active gage.

3. Calibration Check

If the indicating equipment is being used for the first time, it is best to check its calibration before using it. A brief check procedure follows:

- a. Connect the active and compensating gages to the equipment as above, and set the gage factor dial.
- b. Take a zero reading.
- c. Connect a resistor of known value, (R_0), in parallel with the active gage. A resistor of

1. The first step is to determine the type of data being collected. This is done by asking the user to select a data type from a list of options. The options are: text, number, date, time, and boolean.

2. The second step is to determine the range of the data. This is done by asking the user to enter a minimum and maximum value. The user can also choose to enter a range of values.

3. The third step is to determine the format of the data. This is done by asking the user to select a format from a list of options. The options are: standard, scientific, and hexadecimal.

4. The fourth step is to determine the precision of the data. This is done by asking the user to enter a number of decimal places. The user can also choose to enter a range of values.

5. The fifth step is to determine the units of the data. This is done by asking the user to select a unit from a list of options. The options are: none, meters, seconds, and kilograms.

6. The sixth step is to determine the name of the data. This is done by asking the user to enter a name for the data. The name can be up to 255 characters long.

7. The seventh step is to determine the location of the data. This is done by asking the user to select a location from a list of options. The options are: memory, disk, and network.

8. The eighth step is to determine the access mode of the data. This is done by asking the user to select an access mode from a list of options. The options are: read, write, and read/write.

9. The ninth step is to determine the permissions of the data. This is done by asking the user to select a permission from a list of options. The options are: none, read, write, and execute.

10. The tenth step is to determine the security of the data. This is done by asking the user to select a security level from a list of options. The options are: none, low, medium, and high.

about 500,000 ohms is satisfactory.

d. Read the indicator dial, and subtract the zero reading from this second reading to obtain a value in micro-inches which we will call "e".

e. If R_g designates the resistance of the active gage, which is approximately 120 ohms, then R_c referred to in "c" above equals R_g divided by e times the gage factor, G.

$$\text{ie, } R_c = \frac{R_g}{(e)(G)}$$

This computed value of R_c should equal the value of the known resistor.

B. Preparation of Samples

Strips of 61ST6 aluminum about 9 inches long and about 1 inch wide were cut from sheet aluminum 0.091 inches thick. The cutting was done on a metal cutting bandsaw. The edges of the pieces were sanded to remove cutting burrs. Similar strips 0.271 inches thick were cut from 5280 stock. Two samples each of 61ST6 and 5280 were then heated with an oxy-acetylene torch, with an effort being made to simulate the welding and soldering temperatures. As an index to the correct temperature, the pieces were heated until the flame impinging upon the aluminum became tinted with yellow. This was an arbitrary temperature measuring index (which later proved inaccurate) adopted after observing the flame while actually joining pieces of aluminum. The heated pieces were then air cooled.

Another strip of 61ST6 was heated in an electric furnace to the actual temperature required for welding, then allowed to cool in air.

An electric strain gage of the SR4 type was then mounted on the centerline of each piece at about its mid-length.

C. Explanation of the Gage Mounting Procedure

1. Clean the surface upon which the gage is to be mounted. For this purpose, light grinding or sanding with emery cloth may be employed.

2. Degrease the surface with carbon tetrachloride (acetone may be used).

3. Mount the gage:

a. Scribe lines to indicate gage orientation.

b. Coat test surface with a layer of Duco household cement and allow it to dry about 20 minutes.

c. Coat test surface with a second liberal coat of Duco cement and allow it to dry until it becomes slightly tacky.

d. Press gage into position with proper orientation and gradually press out the excess cement with the fingers. Watch the corners of the gage particularly.

e. Keep a slight pressure on the gage until the cement will hold the gage to the surface (about 3 minutes required).

f. Cure the gage:

(1) Cure gages under a slight pressure - about

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...to the ...

7. Evaluation of the data

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1 pound will be sufficient.

(2) Directly on top of the gage, place a layer of waxed paper, then a piece of sponge rubber, then the weight. This combination allows the slight pressure of the weight to hold the gage in place while curing.

(3) Allow gages to cure at room temperature for at least 24 hours. If curing is taking place in an atmosphere of high humidity, allow a longer curing time.

(4) As an alternative to (3) above, an infra-red heating bulb may be placed near the gages, such that a temperature of 150° is maintained, in which case only about 5 hours curing time is required.

4. Cover gages with a light coating of Ceresin wax to keep out moisture. (If testing is being conducted in a laboratory, in all probability no wax coating will be required.)

D. Check of Mounted Gages

After gages have been cured, it is necessary to check them before straining them. The resistance of a strain gage should be about 120 ohms. The leakage resistance to ground should be infinite. By using an ohmmeter, check the above resistances. The gage resistance, in order to be satisfactory, should be within 2 ohms of 120 ohms. The resistance to ground should be at least 50 megohms.

1. Record will be maintained.

(2) Directly on top of the page, place a

label of equal value, then a piece of paper

thinner, than the others. This condition

allows the glass between it and the paper to

hold the paper in place while tested.

(3) After paper is on, it must be

for at least 24 hours. It must be

given in an atmosphere of high humidity,

allow a longer curing time.

(4) As an alternative to (3) above, an

inter-rod testing hole may be placed over

the paper, with this temperature of 100°

is maintained, in which case only about 2

hours curing time is required.

4. Test paper with a light coating of lacquer and

to keep out moisture. (If testing is being conducted in a

laboratory, in all probability no test coating will be required.)

2. Check of finished paper

After paper has been cured, it is necessary to check

them before starting work. The resistance of a single page

should be about 100 ohms. The finished resistance of a group

should be indicated. If high or lower, then the work

testimony. The page resistance, in order to be reliable,

should be within 2 ohms of 100 ohms. The resistance of a group

should be at least 50 ohms.

E. Testing of Samples and Results (See Figures 1 and 2)

The samples were loaded as cantilevers, one end being held with a "C" clamp to a rigid support while the other end received the load.

Loading was accomplished by suspending an empty beer can, into which shot was placed, from a knife edge which rested in a deep scribe mark at the end of the test piece. Loads were varied by varying the amount of shot placed in the can. The shot was weighed on a laboratory balance for accuracy.

Representative results of these tests are shown on the next few pages.

1. Journal of the American Medical Association, 1934, 103: 1000-1001.

The results were similar to those reported by other workers.

With a 10% solution of sodium chloride the results were similar.

Results were similar.

Results were similar to those reported by other workers.

Results were similar to those reported by other workers.

Results were similar to those reported by other workers.

Results were similar to those reported by other workers.

Results were similar to those reported by other workers.

Results were similar to those reported by other workers.

Results were similar.

Modulus Check

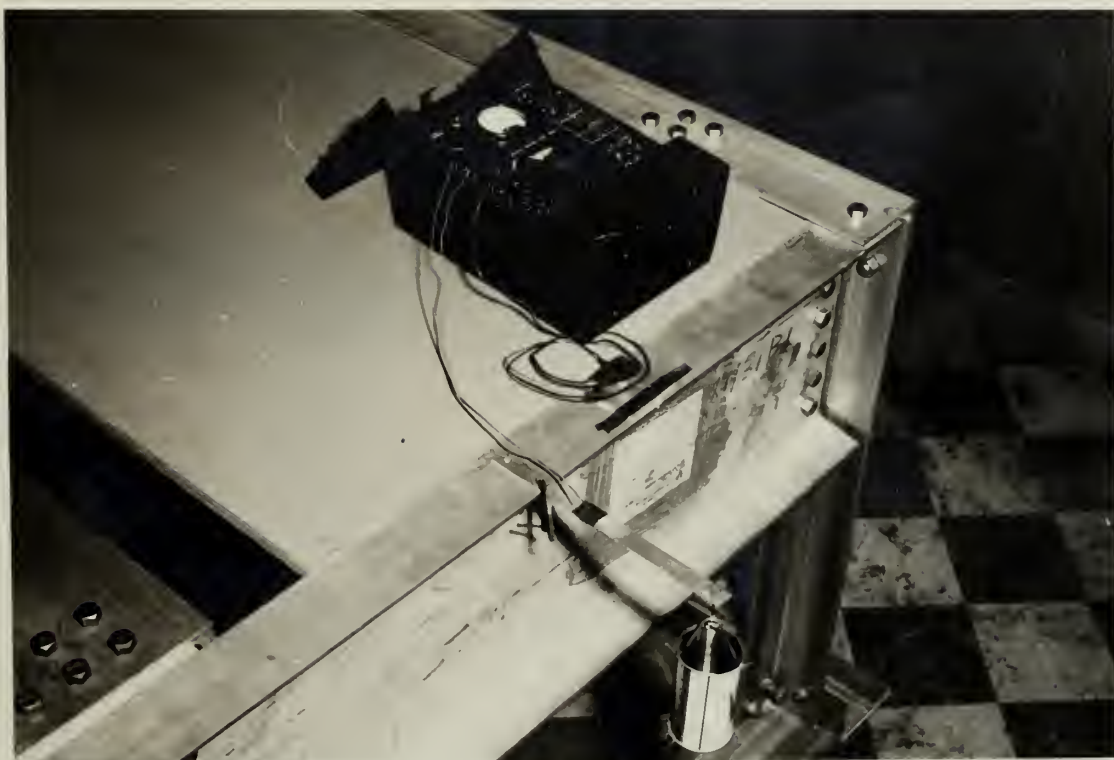


Figure 1



Method of Loading For "E" Check

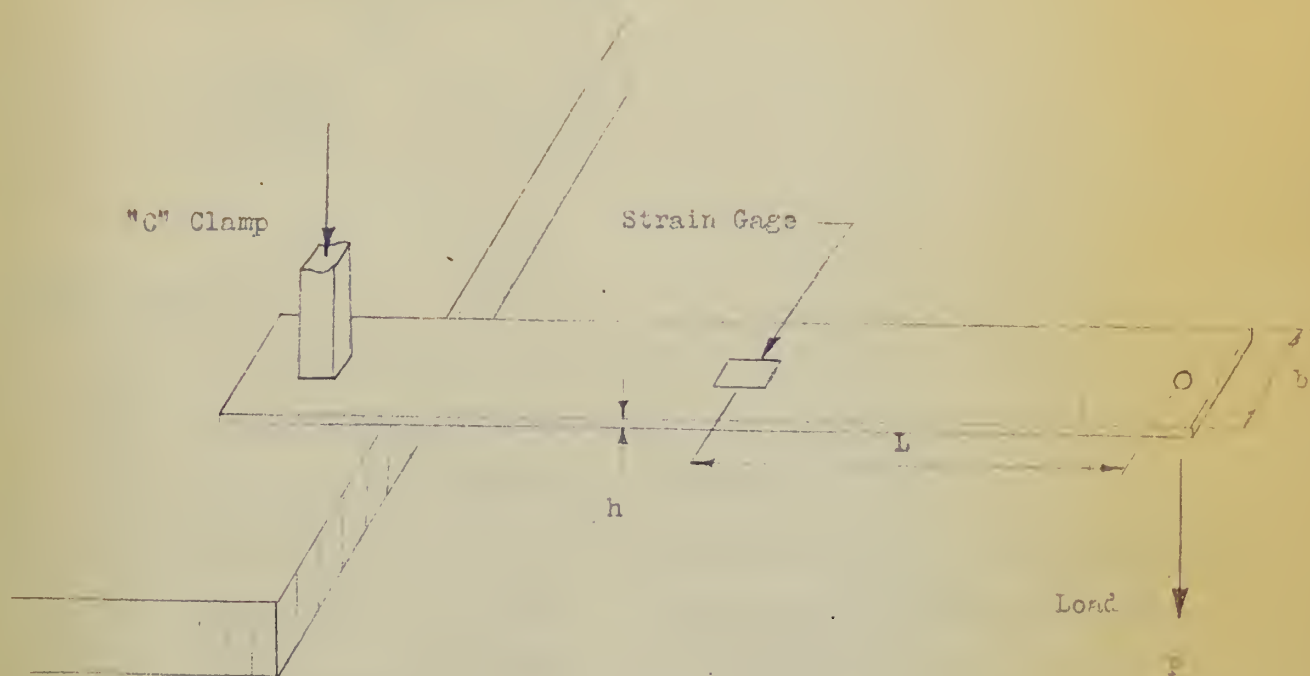


Figure 2



Form of Computations for "E" Check

Computations:

$$I = \frac{bh^3}{12}$$

$$f = \frac{Mc}{I} = \frac{(P)(L)(h/2)}{\left(\frac{bh^3}{12}\right)} = \frac{6 PL}{bh^2}$$

$$E = K \frac{\text{Stress}}{\text{Strain}} = K \frac{f}{e} = \frac{6 PL}{6 \frac{h^2}{e}} K$$

Terms Defined:

I, moment of inertia, inches⁴

b, width of test piece, inches

h, thickness of test piece, inches

f, bending stress in extreme fiber of test piece, lbs/inch²

e, unit strain indicated by SR-4 gage, micro-inches/inch

E, a number proportional to the modulus of elasticity

L, distance from point of application of load to the center of the strain gage, inches

M, bending moment, inch lbs.

K, a constant which corrects the strain indicated by the SR-4 gage to the value actually existing at the extreme fiber of the test piece.

P, load applied, pounds

Continuation:

$$I = \frac{dQ}{dP}$$

$$I = \frac{dQ}{dP} = \frac{dQ}{dP} \cdot \frac{P}{P} = \frac{P}{Q} \cdot \frac{dQ}{dP} = \frac{P}{Q} \cdot \frac{dQ}{dP}$$

$$I = \frac{P}{Q} \cdot \frac{dQ}{dP} = \frac{P}{Q} \cdot \frac{dQ}{dP} = \frac{P}{Q} \cdot \frac{dQ}{dP}$$

Notes on the Foundations for "I" Cases

1. Amount of output, quantity

2. Price of output, price

3. Amount of input, quantity

4. Amount of input in various cases of cost curves, price

5. Unit costs indicated by cost curves, price

6. A function representing the amount of elasticity

7. Amount of output in various cases of cost curves, price

8. Amount of the elastic curve, price

9. Amount of output, price

10. A constant which represents the elastic indicated by the

Cost curve in the case of elasticity indicated by the

Price of the cost curve.

11. Cost curve, price

Heated 618T6 Aluminum

Dimensions of Test piece:

$$b = 0.817 \text{ inches}$$

$$I = 5.21 \times 10^{-5} \text{ inches}^4$$

$$h = 0.091 \text{ inch}$$

$$L = 5.34 \text{ inches}$$

$$E = \frac{P}{e} (.00466)$$

P, lbs.	Strain Reading				
	Zero	Loaded	e	E	f
.25	0924	1043	119	9.78	1165
.50	0924	1161	237	9.82	2330
.75	0923	1281	358	9.78	3490
1.00	0923	1400	477	9.78	4660
*1.25	0923	1519	596	9.78	5840
*1.50	0923	1637	714	9.80	7000

* Strains recorded are those existing 10 minutes after the load was applied. Immediately upon applying the load, the strain was somewhat higher, but gradually decreased to the above values. After 10 minutes, there was no significant change in the strain reading.

TABLE 1

Continued on next page.

1 = 0.001 inch

2 = 0.01 inch

3 = 0.001 inch

4 = 0.01 inch

5 = 0.0001 inch

TABLE 2

Y	X	Z	W	V	U
1.00	0.00	0.00	0.00	0.00	0.00
1.01	0.01	0.01	0.01	0.01	0.01
1.02	0.02	0.02	0.02	0.02	0.02
1.03	0.03	0.03	0.03	0.03	0.03
1.04	0.04	0.04	0.04	0.04	0.04
1.05	0.05	0.05	0.05	0.05	0.05
1.06	0.06	0.06	0.06	0.06	0.06
1.07	0.07	0.07	0.07	0.07	0.07
1.08	0.08	0.08	0.08	0.08	0.08
1.09	0.09	0.09	0.09	0.09	0.09

1 = 0.001 inch

2 = 0.01 inch

3 = 0.001 inch

4 = 0.01 inch

5 = 0.0001 inch

Unheated 61ST6 Aluminum

Dimensions of test piece:

$$b = 0.837 \text{ inches}$$

$$I = 5.33 \times 10^{-5} \text{ inches}^4$$

$$h = 0.0915 \text{ inches}$$

$$L = 5.375 \text{ inches}$$

$$E = \frac{P}{\epsilon} (.00457)$$

Strain Reading

<u>P, lbs.</u>	<u>Zero</u>	<u>Loaded</u>	<u>e</u>	<u>E</u>	<u>f</u>
.25	1498	1617	119	9.60	1143
.50	1497	1735	238	9.60	2281
.75	1496	1853	357	9.60	3430
1.00	1494	1970	476	9.60	4570
*1.25	1493	2086	593	9.62	5700
*1.50	1493	2201	708	9.68	6860

- * Strains recorded are those existing 10 minutes after the load was applied. Immediately upon applying the load, the strain was somewhat higher, but gradually decreased to the above values. After 10 minutes, there was no significant change in the strain reading.

Table of Results

1. 100% of cases
2. 100% of cases
3. 100% of cases
4. 100% of cases
5. 100% of cases

Table of Results

1	2	3	4	5	6
100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100

1. Results reported are based on the following data:
2. Results reported are based on the following data:
3. Results reported are based on the following data:
4. Results reported are based on the following data:
5. Results reported are based on the following data:
6. Results reported are based on the following data:

P. Conclusions on "E" Check

As shown on the preceding pages, the torch heating of the 61ST6 strips changed their value of "E" about 2%. Consistent, stable strain readings were obtained as long as the stresses were below about 5000 psi. For stresses above about 5000 psi, strains fluctuated with time.

Stressing of the 52SO strips, heated and unheated, produced strains which varied radically with time, even at low values of stress. As shown on figures 3 and 4, this variation appears almost linear on a semi-log graph plot. This action appears similar to creep, only in a reversed direction, the test piece seeming to gain strength (i.e., become strained less) the longer the load of constant value remains on it. The authors consulted with members of the Metallurgy Department in an effort to explain this action, but were unable to find a satisfactory answer.

The authors concluded from the results of the above tests that 52SO definitely would not be suitable for a model material, but that 61ST6 would probably be satisfactory.

In an effort to determine the cause of poor results in beams #1 through #7, strips of 61ST6 were placed in an electric furnace to find out the actual temperature required for fusion. It was determined that 1125° F. was required for fusion of the parent metal with the eutecrod filler. The temperature left the metal in a very soft distorted condition after being heated for about 15 minutes. When an effort was made to subject a strip to a flexural load, it collapsed.

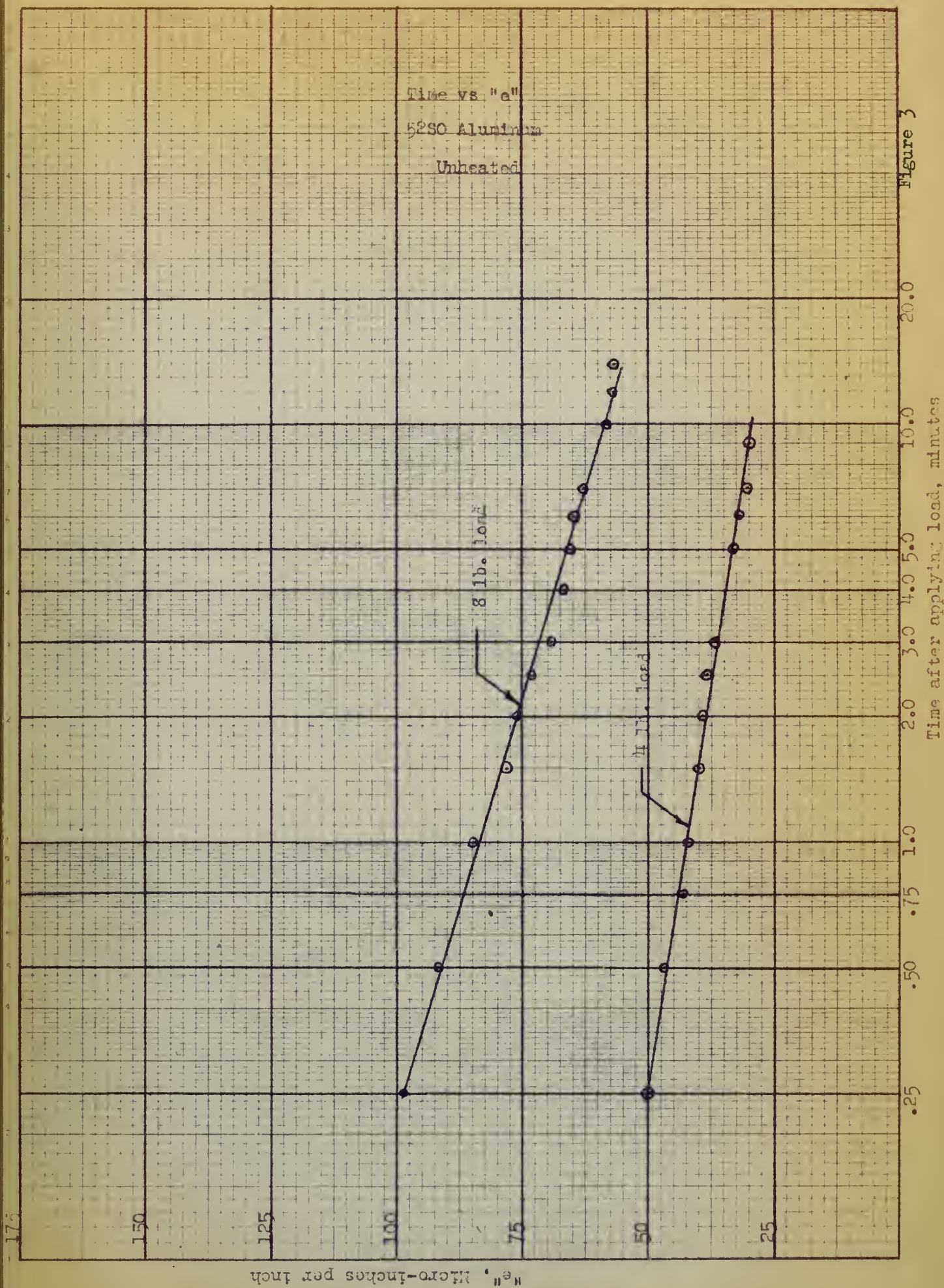
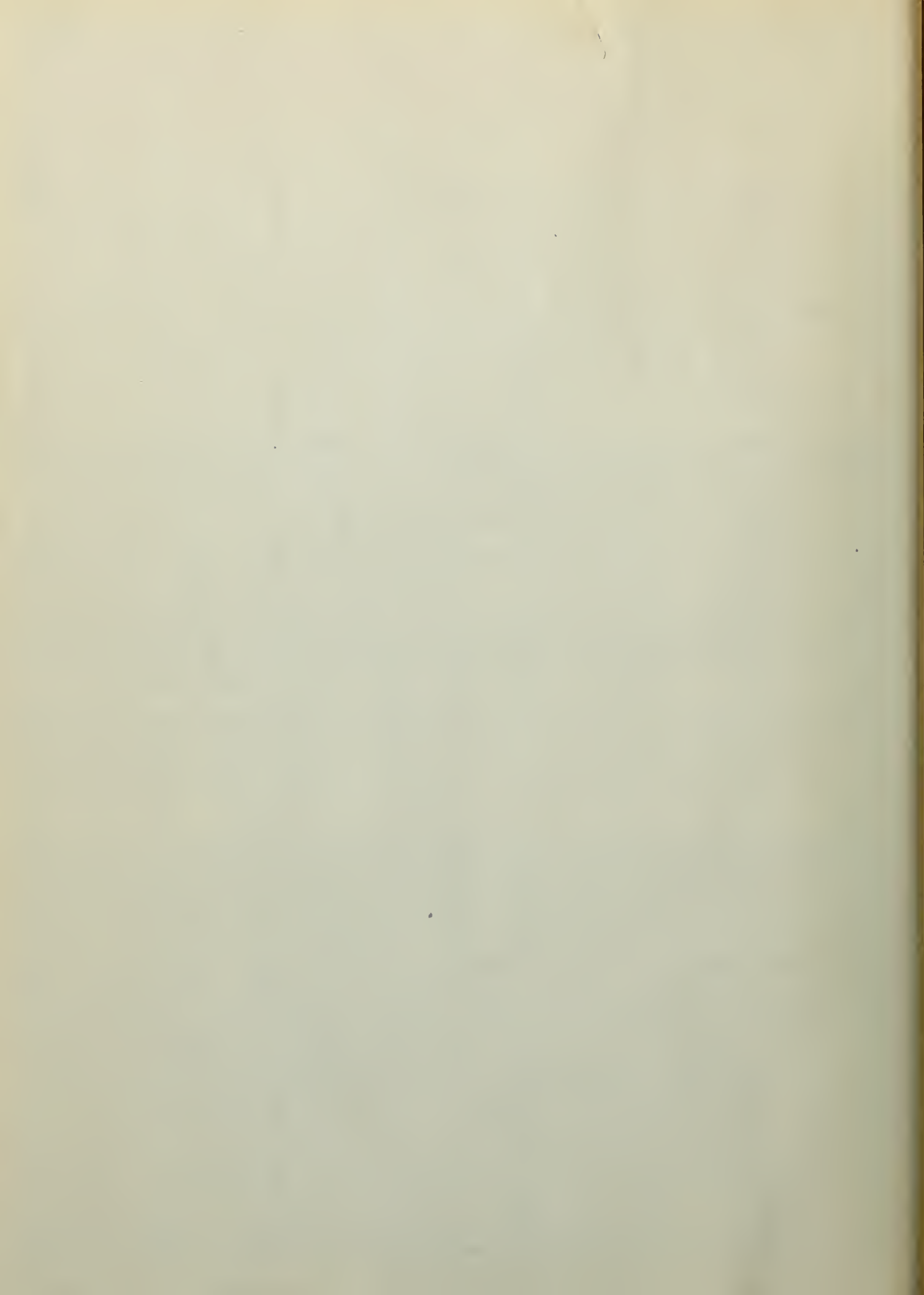


Figure 3



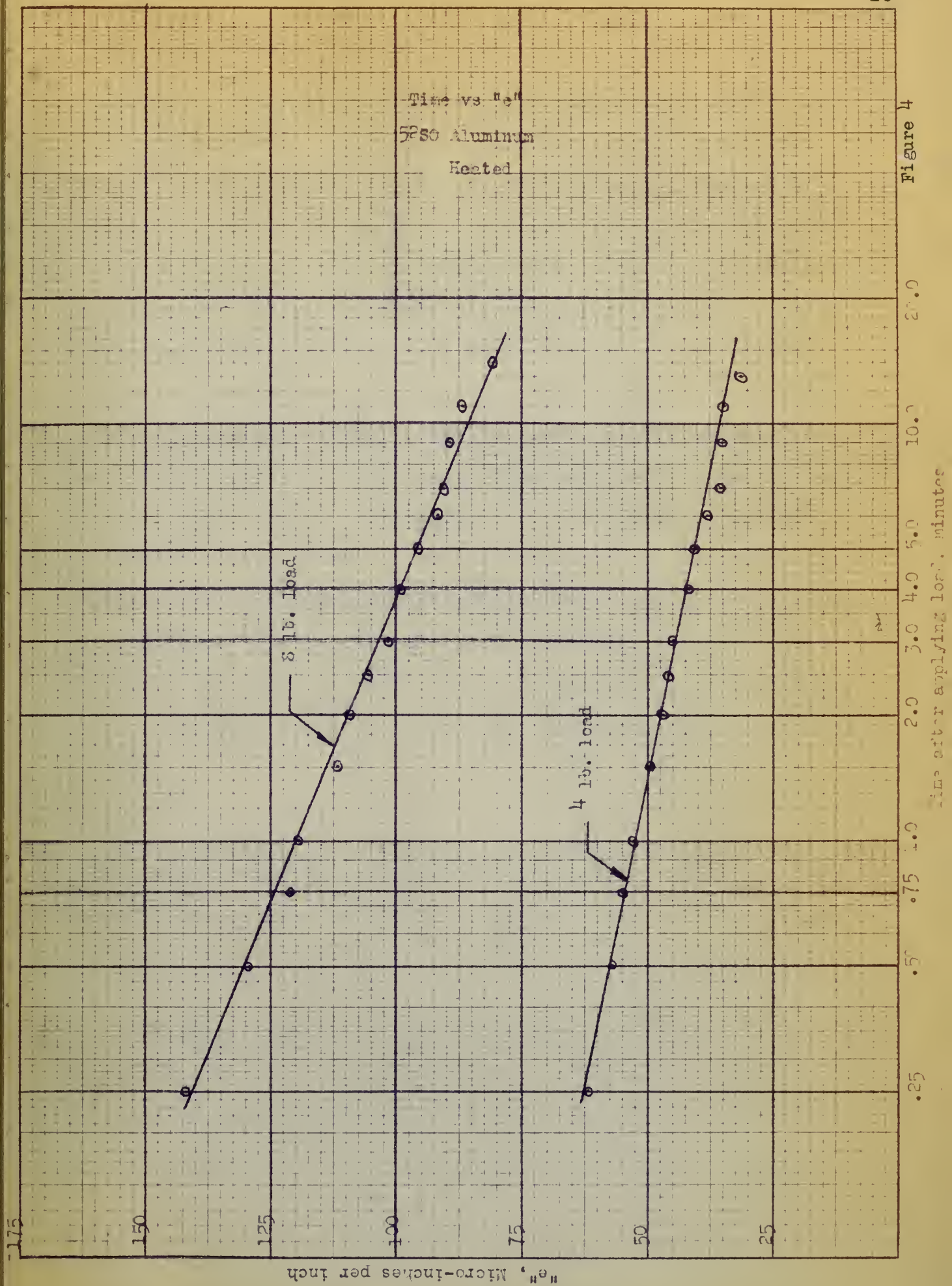


Figure 4



Thus, it was impossible to get strain reading with any meaning from these pieces. The authors concluded that, since these strips had been rendered useless for structural purposes by the temperature required for fusion, at least in the vicinity of the weld when a torch was being used to supply the heat, a similar condition of softness and distortion existed. It was seen, then, that the amount of torch heating given the 61ST6 strips, as determined arbitrarily by the slight discoloration of the flame as it impinged upon the surface of the aluminum, was in reality considerably below the temperature required for fusion during welding with eutecrod. This accounts for the closeness of the valves of "E" as determined in the previous test. (The actual temperature was probably near that required for soldering with the alladin rod.) Welding was then discarded as a method of making aluminum models, and our efforts were concentrated upon the lower temperature alladin soldering method.

III. FABRICATION OF TEST BEAMS

The two materials used for the making of the test beams were steel and aluminum, with the reasons for this choice as dictated in part I. This section is dedicated to the methods and techniques used, and the problems encountered in the fabrication of the test beams. It is divided into two sub parts based on the material used.

A. Aluminum

Aluminum was our first choice for the reasons previously explained. It is best perhaps to begin with the ways the material was prepared.

1. Preparation of Material

The aluminum for the beams was obtained from sheet aluminum of the 61ST6 type, and of varying thicknesses. A metal cutting bandsaw was used to obtain the desired sizes, with great care being taken to insure that straight pieces were obtained. Of interest at this point, would be the fact that it is necessary to be certain that a sharp blade is used in the saw if a straight cut is to be obtained. The sawed edges were next ground down to a smooth finish on a disc sand-wheel and burrs left from this sanding were taken off with a belt sander. This process insured that the extreme edge was not only clean, but also smooth such that close fitting tolerances were obtained when joining pieces. In the making of wide-flange beams in which the web of the beam is butted against the middle of the flange, it is felt by the authors

III. PREPARATION OF TEST SAMPLES

The two materials used for the majority of the test samples were steel and aluminum, with the exception of two test samples discussed in part I. This section is devoted to the methods and techniques used, and the procedures recommended in the preparation of the test samples. It is believed that the methods described in this section will be useful.

A. Aluminum

Aluminum was one of the first metals to be used in the preparation of test samples. It is most popular for testing with the test samples prepared and prepared.

1. Preparation of Material

The aluminum for the tests was obtained from sheet aluminum of the 6110 type, and of varying thicknesses. A metal cutting machine was used to obtain the desired sizes, with great care being taken to insure that straight pieces were obtained. Of interest at this point, would be the fact that it is necessary to be certain that a sharp bend is made in the case of a straight one to be obtained. The reason for this is that when bent down to a sharp bend on a flat surface, the metal will break. This process insured that the surface was not damaged. It also insured that the pieces were straight and not bent. In the making of test samples with combined stress joints, pieces. In the making of stress-strain tests in which one end of the beam is fixed against the middle of the length, it is felt by the authors

that even the thin aluminum oxide present at the joint should be cleaned off. This was accomplished by using a fine emery cloth and cleaning the center of the flange along which the web would touch. The surfaces of the web near the edges were also cleaned up for a short distance, using emery cloth, to insure that the fillet of joining material would have a good surface on which to adhere.

2. Jigs

Making a jig to hold the pieces together while joining them was one of the most difficult problems encountered. We will explain not only the most successful method used, but also the others that were tried. It can be easily understood that the problem of jiggling is not just one of holding the materials, but also a problem of holding them extremely accurately in their correct relation to each other. For example, in the making of wide-flange beams it is necessary that the web be held exactly in the center of the flange. The problem of jiggling is applicable to all the different methods of joining the materials; therefore, it is only necessary to present it once.

At the beginning, the most important problem of jiggling seemed to be one of being able to insure that the pieces were held in exact alignment. It was with this in mind that the first jig was made.

This jig was constructed using three pieces of aluminum angle, lined with asbestos along the outside against

[illegible]

of the beginning, the most important problem of
trying seemed to be one of being able to know that the
process were said in exact alignment. It was with this in
mind that the first list was made.

10-10-68

which the main material would be held, as shown in Figure 5. Angle A and angle B were clamped together to hold the flange securely. Then angle C, which was a cut down angle to give the maximum torch clearance, was used in conjunction with angle A to hold the web securely. As can be seen in the sketch, this method not only gave assurance that the web and the flange were at right angles, but also afforded clear access for measurement to insure that the web was at the midpoint of the flange. The several disadvantages that became apparent in using this method were as follows: (1) in spite of the asbestos lining, too much heat was lost through contact with the metal jig, such that the heating of the piece was irregular and thus the welding temperature, which is very critical, was hard to regulate; (2) the two pieces which were to be joined were both held clamped together, and although of the same material, they warped because of the unequal expansion due to localized heating; and (3) most important, as there was no support for the upper part of the flange, there was a tendency for it to distort to one side or the other due to the concentrated heating near the centerline. Therefore, in the method of welding using eutecrod, as will be explained later, the temperatures required are too high; however, in the soldering method, with the slightly lower temperatures, it might be possible to use the above procedure. The method finally used, as will be explained, seems to be a much more practical way of solving the problem.

Finally, we will be required, even to be a work-
able, to be possible to use the above procedure. The whole
the existing system, with the slightly lower expenditure,
later. The expenditure required was slightly lower, in
in the aspect of relative value, as will be explained
to the proposed system, near the conclusion. Therefore,
was a security for it to be used to our side of the ocean
and we do suggest the two ways of the plan, as
also that by modified method and (b) method, as
the new method, that would require of the system, as
to be joined with the old system, and although it
exists, was said to be (a) and the other way
as suggested and from the existing procedure, which is very
best when the water is, and also the system of the water
of the existing system, two ways of the system, as
system in which the water was as follows: (a) in which
point of the system. The proposed system, as follows
admits the possibility of being that the two ways of the water
the plan was as follows, but also the system of the water
system, this system was only the system, as follows
was to be held the two systems. At the same time
the system of the system, and also in the system of the
accuracy. The system, which was a very good one to the
which a new system was proposed to be the system
which the water was as follows, but also the system of the water

Jig # 1

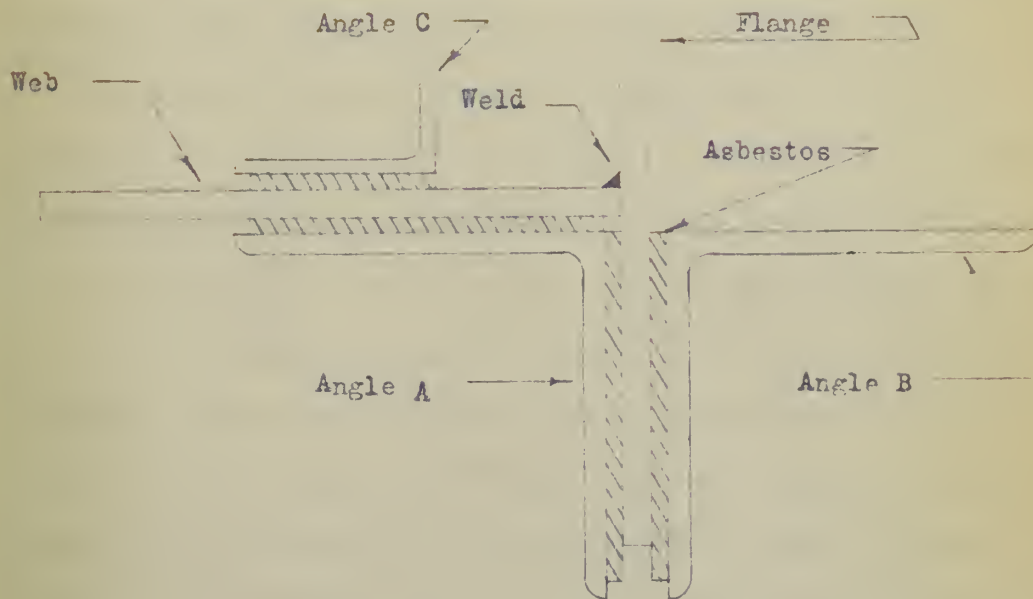


Figure 5



The second jig was made with the idea in mind of being able to support both flanges and the web at the same time to overcome any tendency of these members to warp due to lack of support. We then constructed a jig, the cross section of which is shown in Figure 6. The two angles were made about 30 inches long, which of course limited the length of beam it was possible to make. The angles were lined with asbestos and one was fixed to a base plate to prevent movement. The other angle was made a sliding variety which was held in place by clamping it to the fixed angle with "C" clamps to provide the pressure needed to hold the beam while welding it. The correct location of the web was obtained by using a piece of sheet aluminum bent on a brake such that it held the web up between the two flanges as shown in the sketch. In the process of welding, the two upper welds were placed, the beam was turned over, and the two other welds were placed. This method, at first, seemed to be the solution to all jiggling problems; however, one of the problems encountered in the first jig was present along with a new one. The old problem was that of controlling the heat, and still hadn't been solved. The new problem was as follows. In clamping the two angles together we tried to put just enough pressure to cause the joints to be tight, but not really forced together. This appeared fine from the standpoint of expansion, but still proved inadequate. From the sketch it can be seen that there is no easy way to provide support on top of the web, and still leave room in

The second 10 was made with the idea in mind of

making this 10 roughly the same size as the first
 10 by making the length of the line about the same as
 the 10 of the first. The line was made about
 10 inches long, which of course makes the length of the 10
 not possible to make. The line was made with a
 and was tied to a small piece of wood. The
 other end was made a little longer than the first in place
 by changing it to the first length 10" which is made
 the process needed to hold the line which was 10". The
 second 10 of the 10 was made in the same way as the first of
 about 10 inches long to a small piece of wood. The 10 was
 made the 10 inches as shown in the picture. On the 10th
 of the 10, the 10 inches were made. The 10th was
 made over, and the 10 inches were made. The 10th was
 at 10th, which is the 10th of the 10th. The 10th was
 made, one of the 10th of the 10th. The 10th was
 made with a 10th. The 10th was made with a 10th of
 making the 10th, and will make 10th. The 10th
 was made as follows. On the 10th, the 10th was made
 as follows. The 10th was made as follows. The 10th was
 made, but not really. The 10th was made. The 10th was
 from the 10th of the 10th, and will make 10th. The 10th was
 from the 10th. It can be seen that the 10th is made as
 follows. The 10th is made as follows. The 10th is made as

Jig # 2

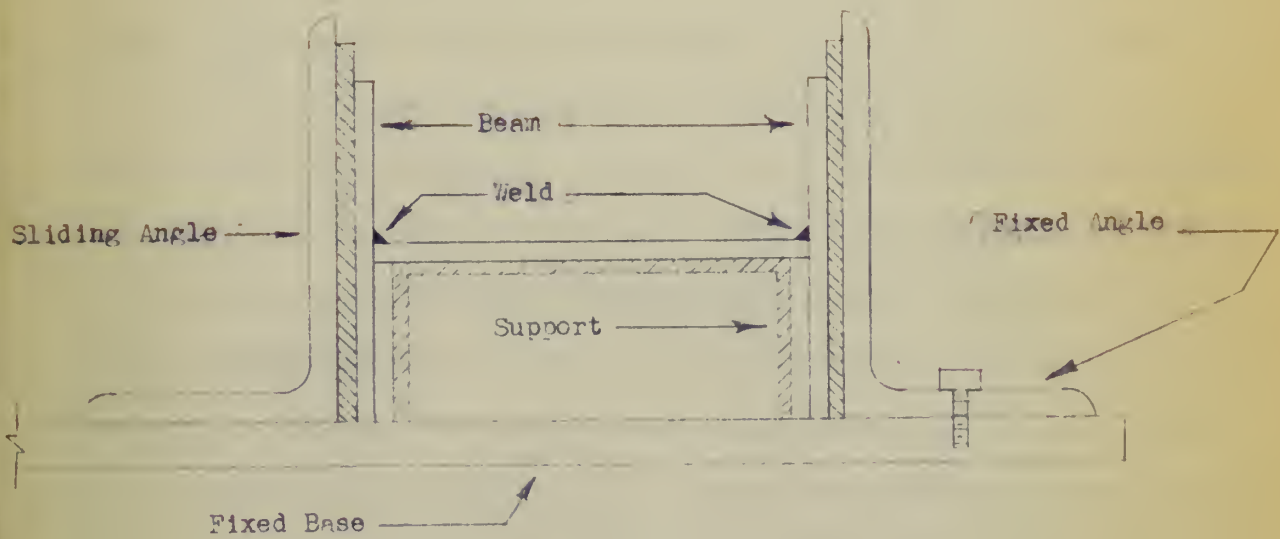


Figure 6



which to use the acetylene torch. Therefore, due to no top support, and the fact that the web was bound to be held by the flanges with more pressure in some places than others, there was a definite tendency for the web to rise off its support and buckle upwards when the heat was applied. The flanges seemed to stay in line, but the method resulted in a beam whose web was not exactly centered between the flanges. Therefore, this beam could not be expected to check according to the deflection theory being used.

Our third design, which eventually led to our final and very successful method, came as an effort to eliminate the defects that were noted in our previous jigs. First of all we wanted to eliminate the heat loss due to contact of other materials with those we were welding. It was also necessary to find some way to support the flanges and web such that they would be held in the proper orientation with respect to each other. These problems were solved by using 1-inch by 1-inch steel angle cut in 3/4-inch lengths. The flange and the web were held at right angles by clamping pieces of the angle to both the web and the flange along one side leaving the other free for welding. Then by adjusting the location of the angle on the flange the web could be placed in the proper location. This arrangement of angles was made along the whole length of the beam, the weld being placed down the free side. However, the flange and the web, which were clamped rigidly together, distorted due to the heating. This resulted in beams which would not check out.

Finally, we used the same method as described in the previous paragraph, but clamped one piece of angle to each side of the flange, directly opposite each other, leaving enough clearance between the angles to insert the web and hold it firm and perpendicular. (See Figures 7 and 8.) The pairs of angles were placed about one foot apart.

A clamp preventing the web and flange from separating, but allowing longitudinal movement, was placed along the beam at each set of angles. The whole beam was then supported on pedestals placed at the mid-point between the angles. This was done such that the beam reaction at the support would keep the joint between the web and the flange tight. The welding was done next, welding first on one side of the web for a length of about 8 inches, then on the other side of the web. It is important not to weld any closer than 2 inches to the angles. The purpose of welding on the opposite side immediately was to utilize the heat that had already been put into the pieces. This also minimized distortion, since stresses resulting from heating on both sides of the web tended to be cancelled out. After the whole beam was welded this way, it was necessary to take off the angles and clamps and weld up the remaining spaces. This method gave us consistent results on all beams constructed, as the results in the following sections will indicate.

3. Check of the Loading Device

It was felt by the authors that a check of the vertical loading frame (see Figure 9) was necessary in order

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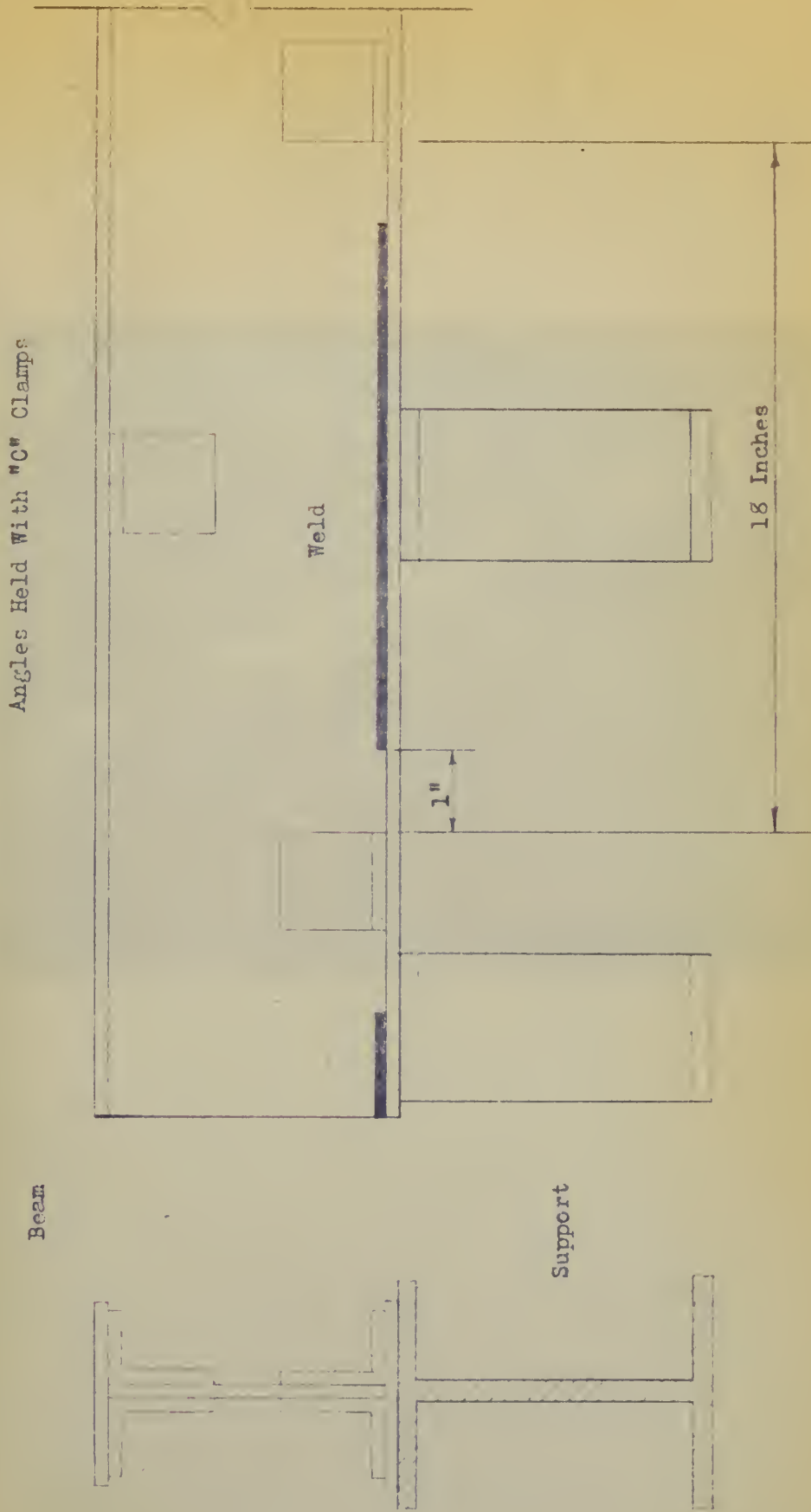
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Jig # 3 Modified

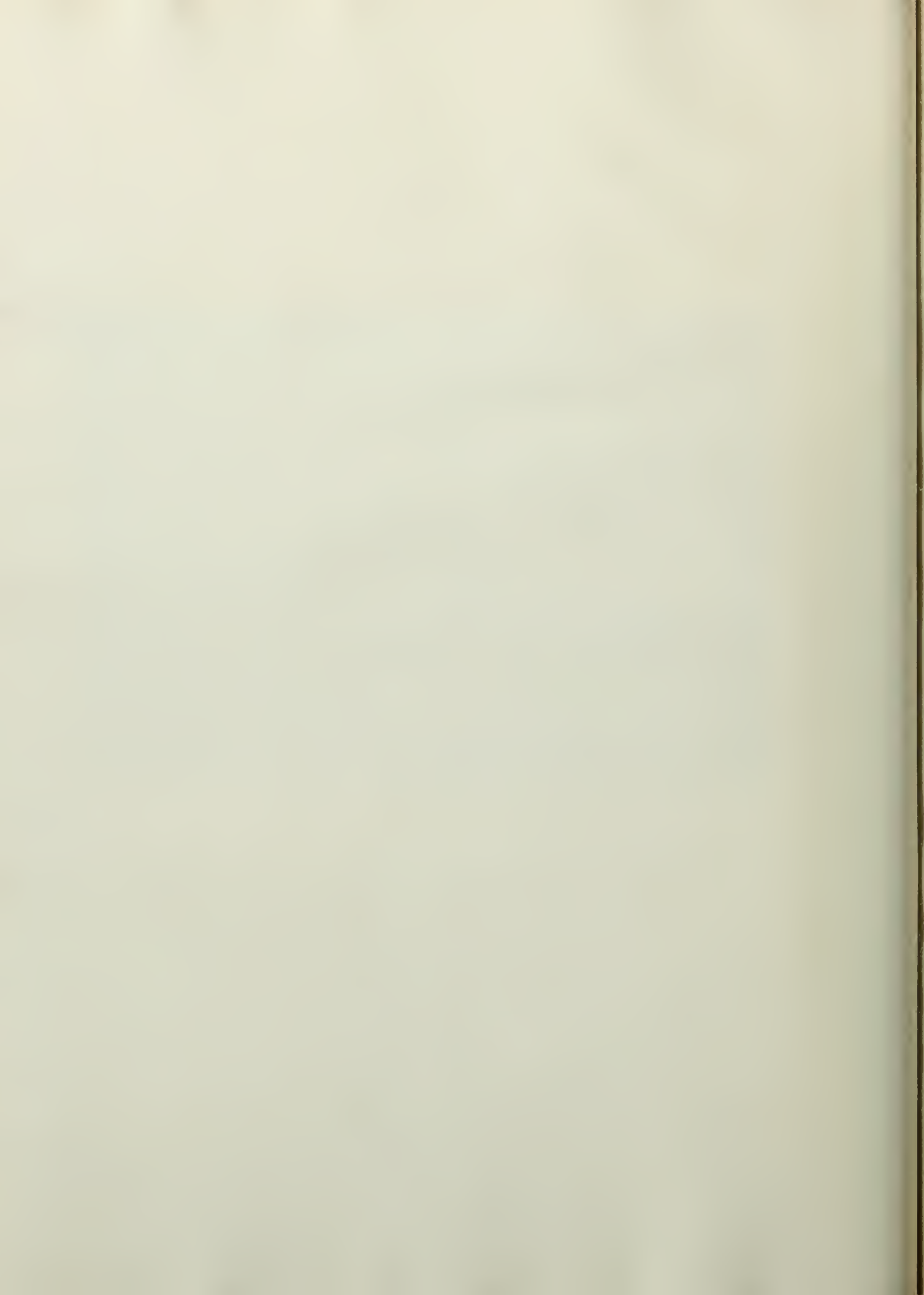
Figure 7



Jig #3 Modified



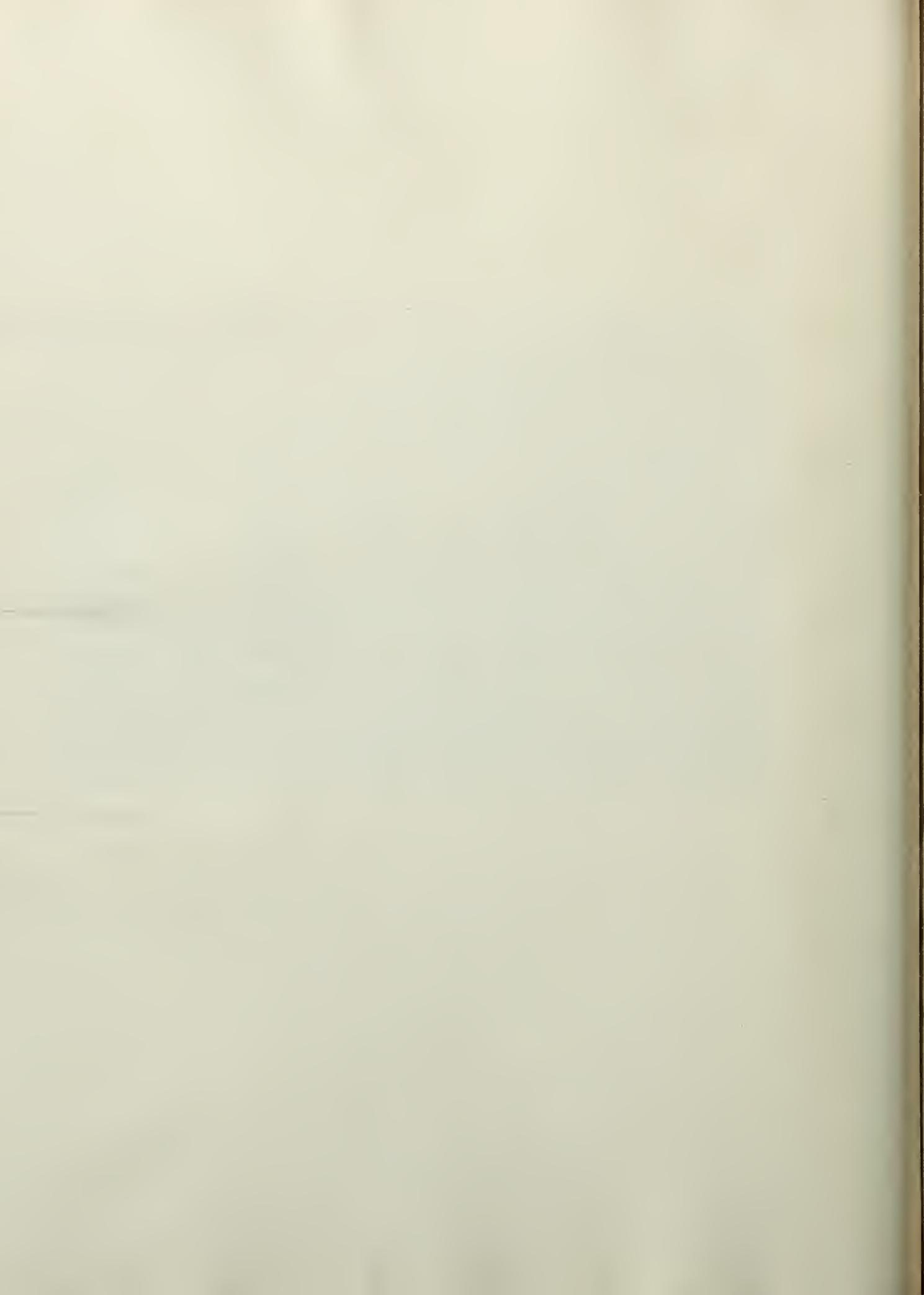
Figure 8



Vertical Loading Frame



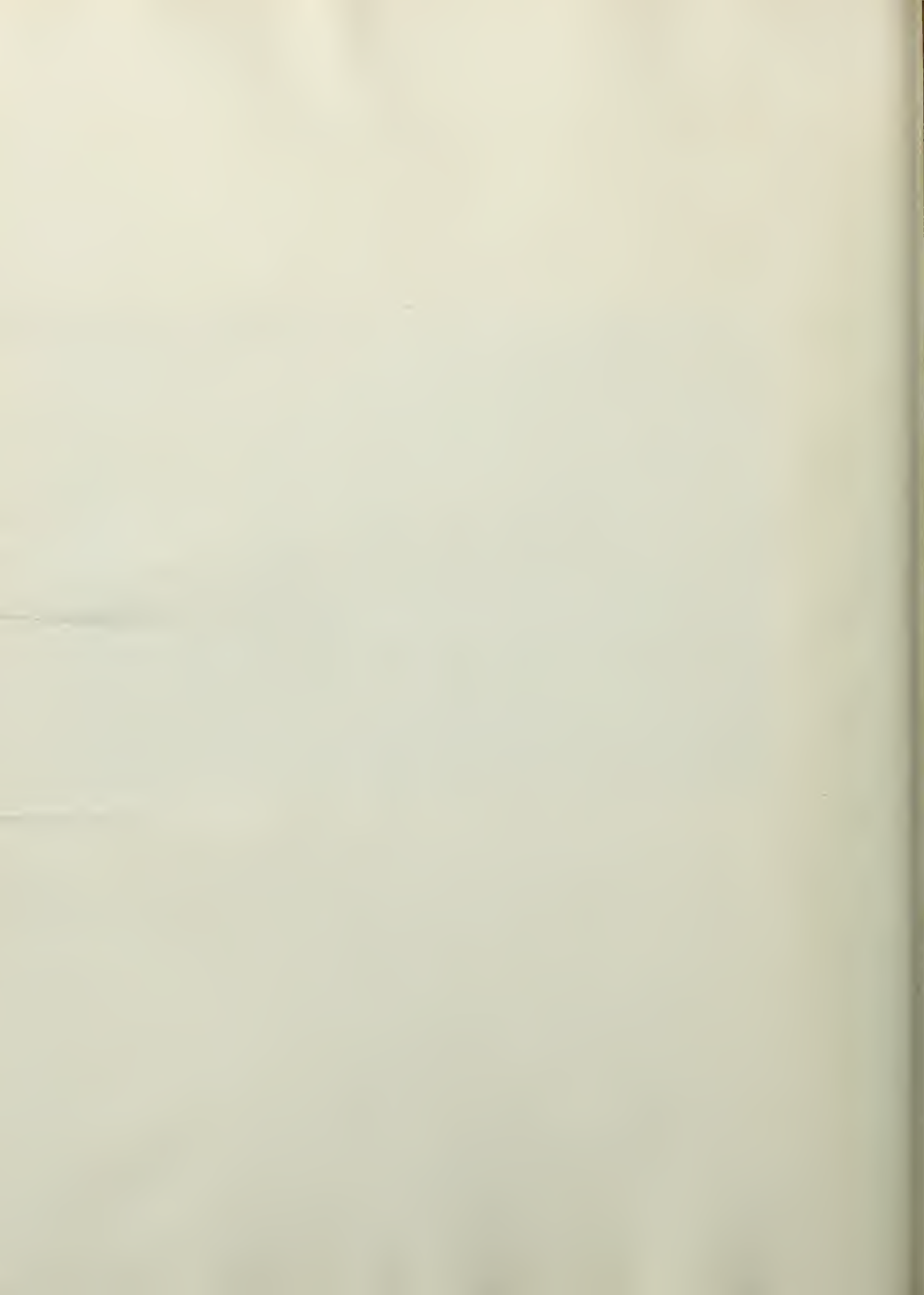
Figure 9



to insure that accurate results would be obtained. Therefore, an extruded "T" beam was obtained and subjected to a load test on the loading frame. The method used to check our procedure consisted of loading the beam and comparing the actual and computed deflections. This set up is shown in Figure 10.

The beam, when in the loading frame, was supported on knife edges which were rounded on the underneath side so that no restraint was placed on them. The load consisted of lead shot placed in a bucket. It was applied to the beam by means of a knife edge, attached to a yoke (see Figure 11) which supported the bucket. The deflection was measured by a 1/10,000 of an inch direct reading dial, placed underneath the mid-point of the span. The dial holder is shown in Figure 11 and was made such that it would also serve as a dial holder for taking readings on the horizontal loading frame.

A comparison of the actual deflections, under load, with the deflections computed by conventional formulae show an average difference of 1.4%. This check was considered close enough to allow the use of this vertical loading frame for future model tests.



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to insure that accurate results would be obtained. Therefore, an estimate of the error was obtained and subjected to a test for the loading time. The method used to check the procedure consisted of loading the beam and comparing the actual and computed deflections. This test is shown in figure 10.

The beam, when in the loading frame, was supported on knife edges which were mounted on the undercarriage of the test machine. The beam was placed on them. The beam consisted of two equal parts in a doublet. It was applied to the beam by means of a knife edge, attached to a yoke (see figure 11) which supported the weight. The deflection was measured by a dial indicator at an inch direct reading dial, placed underneath the mid-point of the beam. The dial indicator is shown in figure 12 and was used to find the deflection of the beam as a dial indicator for testing beams on the horizontal loading frame.

A comparison of the actual deflection, δ_{act} , with the deflection computed by theoretical formulas gave an average difference of 1.4%. This shows the computation close enough to allow the use of this vertical loading frame for future model tests.



All Dimensions are in inches.

Computations:

Moment of Inertia,

$$I_{\text{flange}} = \frac{2(bt^3 + btc^2)}{12}, \quad I_{\text{web}} = \frac{t(d-t)^3}{12}$$

I Total equals I flange + I web.

Deflection,

$$D = \frac{PL^3}{48 EI}$$

D- Deflection in inches
L- Span length in inches
E- Modulus of Elasticity
I- Moment of Inertia
P- Load in pounds

Stress

$$f = \frac{Mc}{I}$$

f- Stress in psi
M- Moment in inch-pounds
I- Moment of Inertia
c- As shown above

Figure 10

Loading Yoke and Deflection
Dial Holder

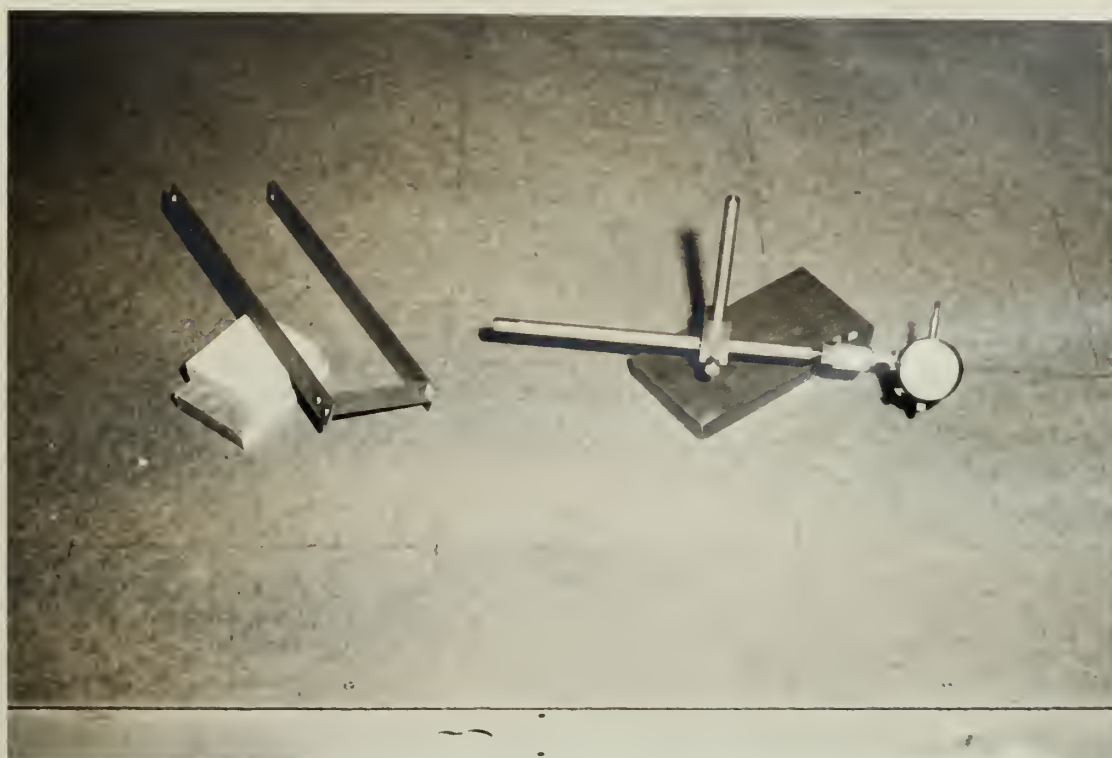


Figure 11

Extruded "T" Beam

(Beam #1)

Dimensions of Beam
(See Figure 10)

b = 1.24 inches
t = .128 inches
d = .87 inches
L = 34 inches

Neutral Axis was computed to be .227 inches above the base.

Moment of inertia (I) = .0158 inches⁴

Deflection (D) = $5.18 P (10^{-3})$

Stress (f) = 345 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Dif.</u>	<u>Stress</u>
1.6	.07551	.08330	.00801	.00830	0	551.0
2.16	.07566	.08679	.01128	.01123	.45	745.0
3.0	.07555	.09170	.01604	.01555	3.05	1035.0
4.0	.07560	.09708	.02153	.02073	3.72	1380.0
5.0	.07560	.10160	.02600	.02590	.38	1720.0
7.0	.07561	.11201	.03641	.03630	.32	2320.0
9.0	.07561	.12314	.04753	.04670	1.74	3100.0
11.0	.07561	.13320	.05759	.05700	1.02	3800.0
13.0	.07561	.14382	.06821	.06730	1.33	4480.0
15.0	.07561	.15489	.07928	.07775	1.93	5180.0

4. Technique of Joining Flanges to Web

There were three methods used by the authors in fabricating models from aluminum. They were eutecrod welding, soldering, and furnace brazing. It is in this section that we will discuss the three methods and the results of the tests run on the models constructed by each method.

a. Eutecrod Welding

(1) Welding difficulties

The difficulty in welding with eutecrod is the high temperature required for fusion, which approaches the melting temperature of aluminum. In actual practice the two temperatures differ only by about 50 degrees and great care must be exercised not to bridge this differential. The parent material will warp and disintegrate very quickly when the melting point is approached. Another important point to consider is that, in the vicinity of the weld, the yield strength of the material has decreased considerably, resulting in the material no longer being homogeneous. These two facts are very important and must be considered in view of the final results desired.

(2) Flux

The flux used was supplied by the eutecrod company to be used in conjunction with their rod. It is a powder that is mixed with

men on the models constructed by each method, we will discuss the three methods and the types of the tests utilized, and further describe, in an additional part, the testing models from which they were selected. There were three systems used by the subjects in

$$= \frac{1}{\sqrt{\pi}} \int_0^{\infty} \cos(xt) dt = \delta(x) \quad (1)$$
[illegible]

张明 王明 (五)

The first news was supplied by the nurses -
and they say he was in a condition with
himself. It is a wonder that he lived with

water to form a paste, which is spread on the joint to be welded. Care must be exercised in applying the flux, insuring that only the surfaces at the joint are covered. This is true because, if too much is used, the flux allows the eutectoid to run as it melts, covering a weld area that is too large. This point is not essential in making a good weld but it appears to help.

(3) Method of welding (See Figure 12)

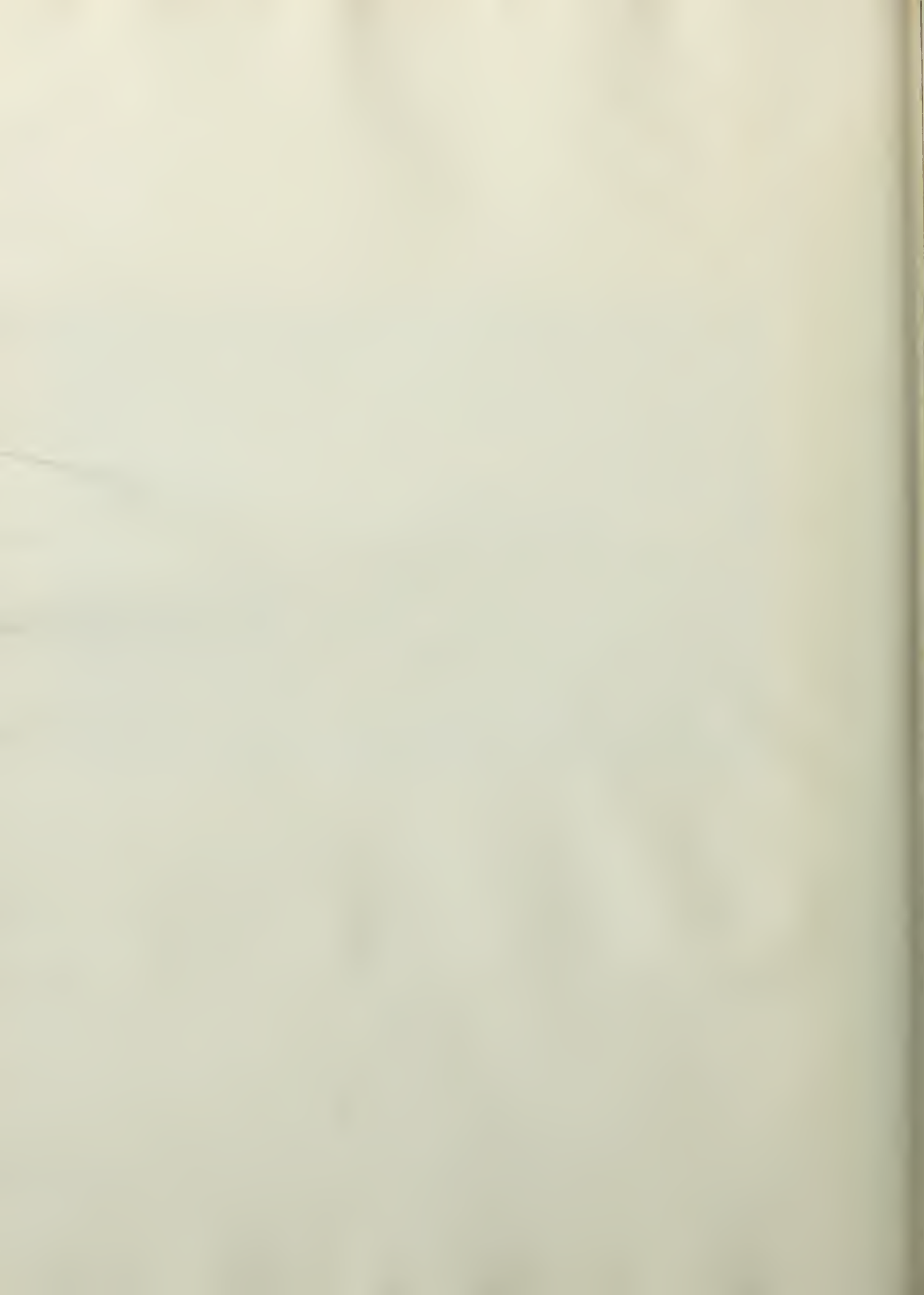
The actual method used in welding is similar to that used in any torch welding, with a modification. The big change adopted was in the way the heat from the torch was applied to the joint. Rather than directing the flame almost perpendicular to the joint, we found it better to shoot the flame parallel to the joint, heating with the side of the flame. Using this method, it was found that there was better control of the heat, giving effective preheating with less chance of overheating. The rest of the welding procedure is the same, i.e., feeding in welding rod as the temperature gets high enough, and moving along fast enough to give an even fillet.

1811

Method of Welding



Figure 12



(4) Test Samples and Results

In order to be sure of the amount of load eutecrod welding would sustain, a series of test samples were made. They were of the form as shown in Figure 13 with the dimensions and results as shown below.

Shear test

a = 1 inch
L = 2 inches
b = 3/4 inch
h = .091 inch

Under a load (P) of 1590 pounds, the parent material broke across the 3/4 inch dimension.

Tension test

a = 1 inch
b = 3/4 inch
h = .091 inch

Under a load (P) of 980 pounds, the weld broke.

The results of these tests were definite proof that any welds made with eutecrod were sufficiently strong to withstand more load than the parent material, and therefore, strong enough to carry the loads we would use.

(4) Test Results and Remarks

In order to be sure of the amount of load sustained during welding, a series of test results were made. They were of the form as shown in Figure 12 with the dimensions and results as shown below.

Lower Test

$a = 1$	inch
$b = 2$	inch
$c = 2\sqrt{2}$	inch
$d = 2\sqrt{2}$	inch

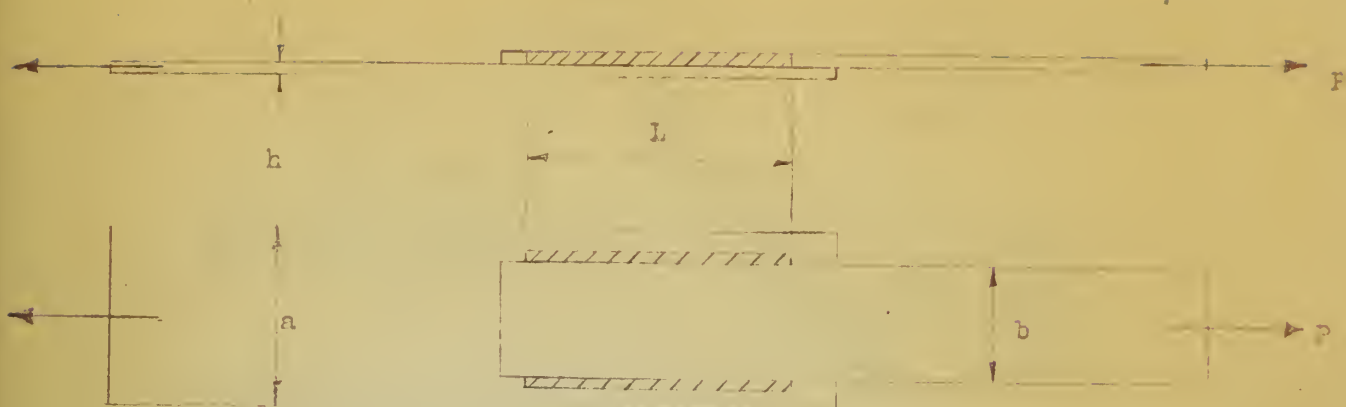
Under a load (1) of 1000 pounds, the plates yielded about across the $2\sqrt{2}$ inch dimension.

Upper Test

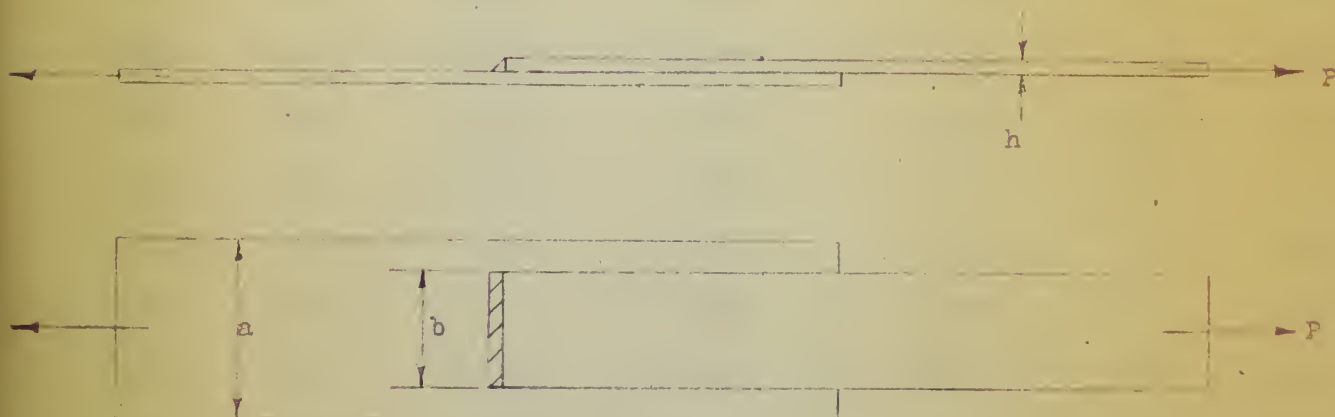
$a = 1$	inch
$b = 2\sqrt{2}$	inch
$c = 2\sqrt{2}$	inch

Under a load (1) of 100 pounds, the weld broke. The results of these tests were as follows. It was noted that the weld broke with excessive force. This was due to the fact that the plates were not sufficiently strong to withstand more load than the plates yielded, and therefore, stress should be kept the load as much as possible.

Shear and Tension Test Specimen

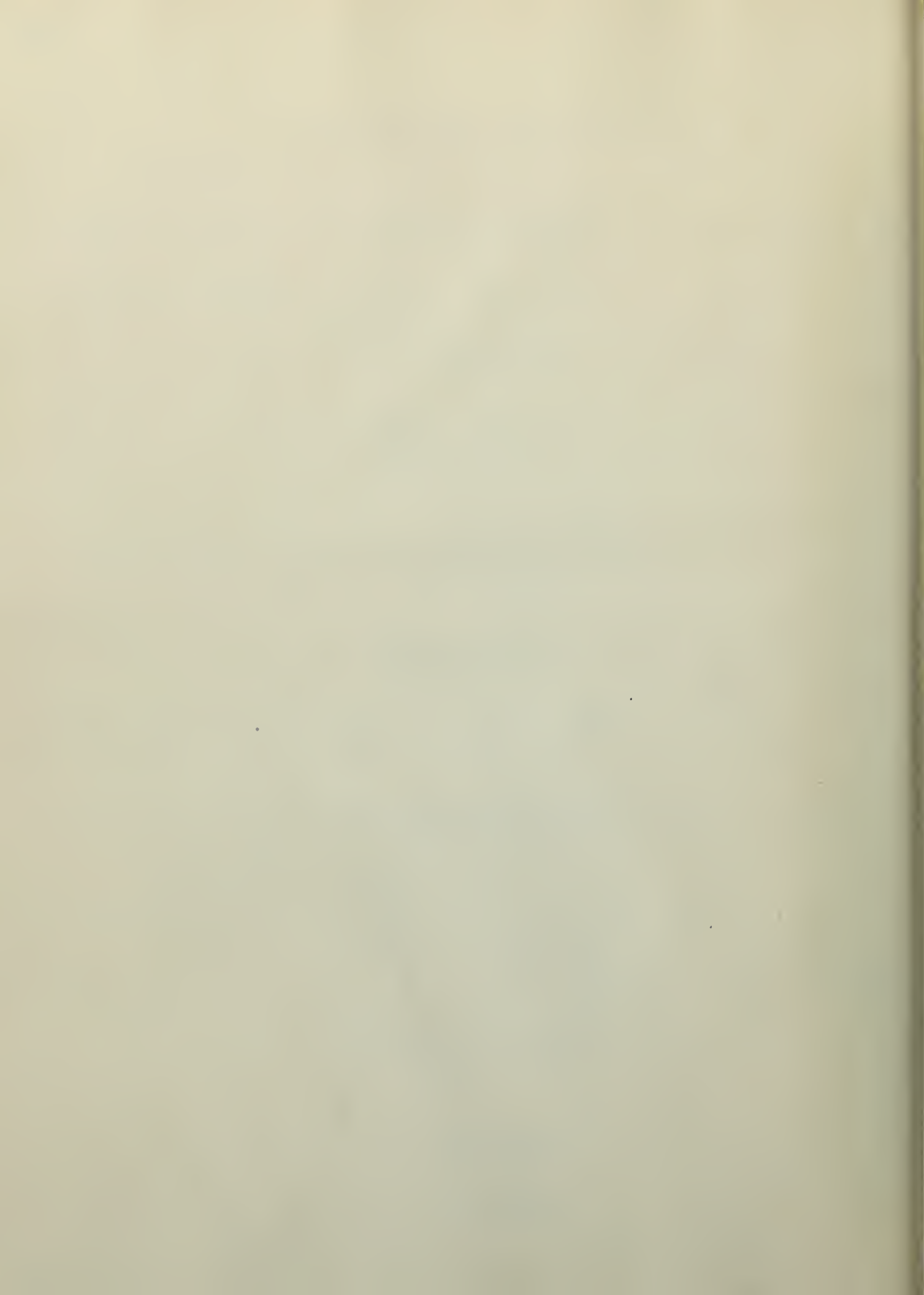


Shear Test



Tension Test

Figure 13



(5) Aluminum welded beam tests and results

Beam #4

Beam #4 was constructed, using the eutecrod welding method, in jig #2. It was tested on the vertical loading frame with the results as given below.

Dimensions of Beam
(See Figure 10)

b = 2.0 inches
t = .093 inches
c = 1.32 inches
d = 2.73 inches
L = 24 inches

Moment of Inertia (I) = .7750

Deflection (D) = $.0371 \times 10^{-3} P$

Stress (f) = 10.2 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.2800	.2831	.0031	.00037	87.0	102.0
26.6	.2800	.2845	.0045	.0010	78.0	272.0
35.0	.2821	.2859	.0038	.0013	66.0	357.0
50.6	.2823	.2875	.0052	.0019	63.0	516.0
60.0	.2826	.2882	.0056	.0022	61.0	612.0
75.6	.2828	.2901	.0073	.0028	62.0	771.0
85.0	.2829	.2916	.0087	.0032	63.0	867.0
100.6	.2831	.2928	.0097	.0037	62.0	1020.0
110.0	.2832	.2936	.0104	.0041	61.0	1121.0
125.6	.2836	.2946	.0110	.0047	57.0	1280.0
135.0	.2839	.2949	.0110	.0050	55.0	1379.0
150.6	.2839	.2976	.0137	.0056	59.0	1537.0

(6) Aluminum nitrate was used as a catalyst.

Table 4

Some of the characteristics of the polymerized material, in the form of a solid, is given in Table 4. It was found that the polymerized material, in the form of a solid, is given in Table 4. It was found that the polymerized material, in the form of a solid, is given in Table 4.

Aluminum nitrate	0.5	0.5
Aluminum nitrate	1.0	1.0
Aluminum nitrate	1.5	1.5
Aluminum nitrate	2.0	2.0
Aluminum nitrate	2.5	2.5
Aluminum nitrate	3.0	3.0

Amount of catalyst (1) = 0.5 g.

Concentration (1) = 0.05 M in 10% v/v

Time (1) = 10.0 h

Table 5

Time	Temp.	Conc.	Yield	Viscosity	Color	Notes
0.5	0.5	0.5	0.5	0.5	0.5	0.5
1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.5	1.5	1.5	1.5	1.5	1.5	1.5
2.0	2.0	2.0	2.0	2.0	2.0	2.0
2.5	2.5	2.5	2.5	2.5	2.5	2.5
3.0	3.0	3.0	3.0	3.0	3.0	3.0
3.5	3.5	3.5	3.5	3.5	3.5	3.5
4.0	4.0	4.0	4.0	4.0	4.0	4.0
4.5	4.5	4.5	4.5	4.5	4.5	4.5
5.0	5.0	5.0	5.0	5.0	5.0	5.0
5.5	5.5	5.5	5.5	5.5	5.5	5.5
6.0	6.0	6.0	6.0	6.0	6.0	6.0
6.5	6.5	6.5	6.5	6.5	6.5	6.5
7.0	7.0	7.0	7.0	7.0	7.0	7.0
7.5	7.5	7.5	7.5	7.5	7.5	7.5
8.0	8.0	8.0	8.0	8.0	8.0	8.0
8.5	8.5	8.5	8.5	8.5	8.5	8.5
9.0	9.0	9.0	9.0	9.0	9.0	9.0
9.5	9.5	9.5	9.5	9.5	9.5	9.5
10.0	10.0	10.0	10.0	10.0	10.0	10.0

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
160.0	.2844	.2981	.0137	.0059	57.0	1631.0
185.0	.2849	.2997	.0148	.0068	54.0	1889.0
215.5	.2850	.3004	.0154	.0080	48.0	2195.0

Beam #4 was warped and distorted which accounts for the high percentage error. These high errors indicate that the whole method was entirely inadequate for a simple laboratory technique. The next attempt at eutecrod welding was Beam #7.

<u>Year</u>	<u>1910</u>	<u>1911</u>	<u>1912</u>	<u>1913</u>	<u>1914</u>	<u>1915</u>
1910	1000	1000	1000	1000	1000	1000
1911	1000	1000	1000	1000	1000	1000
1912	1000	1000	1000	1000	1000	1000
1913	1000	1000	1000	1000	1000	1000
1914	1000	1000	1000	1000	1000	1000
1915	1000	1000	1000	1000	1000	1000

The first attempt at a survey of the
 high altitude area was made in 1910
 and the results were published in 1911.
 The next attempt at a survey was made in 1912.

<u>Year</u>	<u>1910</u>	<u>1911</u>	<u>1912</u>	<u>1913</u>	<u>1914</u>	<u>1915</u>
1910	1000	1000	1000	1000	1000	1000
1911	1000	1000	1000	1000	1000	1000
1912	1000	1000	1000	1000	1000	1000
1913	1000	1000	1000	1000	1000	1000
1914	1000	1000	1000	1000	1000	1000
1915	1000	1000	1000	1000	1000	1000
1916	1000	1000	1000	1000	1000	1000
1917	1000	1000	1000	1000	1000	1000
1918	1000	1000	1000	1000	1000	1000
1919	1000	1000	1000	1000	1000	1000
1920	1000	1000	1000	1000	1000	1000
1921	1000	1000	1000	1000	1000	1000
1922	1000	1000	1000	1000	1000	1000
1923	1000	1000	1000	1000	1000	1000
1924	1000	1000	1000	1000	1000	1000
1925	1000	1000	1000	1000	1000	1000

Beam #7

Beam #7 was constructed using the autecrod welding method in jig #3. It was tested on the vertical loading frame with the results as follows:

Dimensions of Beam
(See Figure 10)

b = 1.03 inches
t = .063 inches
c = .55 inches
d = 1.16 inches
L = 12 inches

Moment of Inertia (I) = .0455

Deflection (D) = $.0791 \times 10^{-3} P$

Stress (f) = 36.2 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.2337	.2341	.0004	.000127	67.5	58.0
5	.2337	.2347	.0010	.000396	60.4	181.0
12.2	.2337	.2357	.0020	.000963	52.0	442.0
19.85	.2335	.2364	.0029	.00157	48.3	719.0
27.85	.2338	.2373	.0035	.00220	37.0	1005.0
35.7	.2338	.2379	.0041	.00283	31.0	1290.0
42.65	.2340	.2389	.0049	.00337	31.2	1540.0
51.1	.2340	.2400	.0060	.00403	32.8	1850.0
58.85	.2341	.2410	.0069	.00465	32.6	2130.0
66.35	.2343	.2416	.0073	.00525	28.7	2400.0
74.65	.2341	.2428	.0087	.00590	32.2	2750.0
110.00	.2339	.2470	.0130	.00870	33.1	3980.0
160.0	.2340	.2518	.0175	.01265	28.0	5800.0

Table IV was determined using the average welding values

in Table IV. It was found that the average values were

the average of the following:

1.15 inches	1.15 inches	1.15 inches
1.15 inches	1.15 inches	1.15 inches
1.15 inches	1.15 inches	1.15 inches
1.15 inches	1.15 inches	1.15 inches
1.15 inches	1.15 inches	1.15 inches

Sum of all values (1) = 1.15

Deflection (2) = 0.001 x 10-3

Stress (3) = 30.0

Load	Deflection	Stress	Load	Deflection	Stress
1.0	0.001	30.0	1.0	0.001	30.0
2.0	0.002	60.0	2.0	0.002	60.0
3.0	0.003	90.0	3.0	0.003	90.0
4.0	0.004	120.0	4.0	0.004	120.0
5.0	0.005	150.0	5.0	0.005	150.0
6.0	0.006	180.0	6.0	0.006	180.0
7.0	0.007	210.0	7.0	0.007	210.0
8.0	0.008	240.0	8.0	0.008	240.0
9.0	0.009	270.0	9.0	0.009	270.0
10.0	0.010	300.0	10.0	0.010	300.0
11.0	0.011	330.0	11.0	0.011	330.0
12.0	0.012	360.0	12.0	0.012	360.0
13.0	0.013	390.0	13.0	0.013	390.0
14.0	0.014	420.0	14.0	0.014	420.0
15.0	0.015	450.0	15.0	0.015	450.0

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
185.0	.2343	.2540	.0197	.01462	25.8	6700.0
235.0	.2350	.2603	.0253	.01860	26.5	8500.0
259.8	.2362	.2644	.0282	.0205	27.4	9370.0
283.0	.2362	.2680	.0318	.0223	29.9	10,500.0

The readings taken on Beam #7 were consistently better than those on Beam #4, but the percentage error was still much too high to accept this method as a way for building models. It appears that, due to the localized heating, there is a definite zone of softening in the area of the weld which caused the beam to act irregularly.

b. Aluminum Soldering

The method of using aluminum solder as a means of constructing our model beams was investigated at the same time as the eutecrod method. The two methods are very similar, and their similarities along with the differences will be presented in this section.

(1) Characteristics of Solder

Alladin soldering is not as strong as eutecrod welding. However, once the limitations were discovered, it was possible to use it with considerable success. The solder melts at a much lower temperature than does welding rod. This most important characteristic makes it much easier to use since the melting point of the parent material is not approached. However, since there is no direct fusion of material, the strength of the joint is definitely decreased. The sample pull test results will indicate this much more clearly. The rod used was an alladin rod. This particular rod required no flux. Therefore, it was necessary to insure that all oxides were cleaned off the aluminum prior to soldering. In addition, a reducing flame was used to prevent the formation of any oxides while soldering.

B. Aluminum Soldering

The action of using aluminum solder is a means of dissolving the metal surface and is performed at the same time as the soldering process. The first method is very simple, and easily identifiable also with the other methods will be described in this manner.

(1) Preparation of Solder

Aluminum soldering is not as strong as expected welding. However, when the solder is first prepared, it is possible to use it with considerable success. The solder acts as a much faster component than does welding rod. This most important characteristic makes it much easier to use since the melting point of the parent material is not approached. However, some care is not taken (even of material), the strength of the joint is definitely weakened. The amount of lead present will depend on the amount of alloy. The use of the aluminum rod. This particular rod is used as filler. Consequently, it is necessary to insure that all sides were cleaned off the aluminum prior to soldering. In addition, a reduced time was used to prevent the formation of any oxide film.

The method of cleaning the aluminum was the same as that outlined under eutecrod welding. Of the two size rods available, the 1/16" rod was preferred to the 1/8" rod due to the size of the sections being joined. There was only one difficulty encountered, other than those mentioned under eutecrod welding. It was noticed that the solder already placed tended to ball up in some places along the joint when placing solder on the opposite side. This occurred only in a few locations, however, and was patched up easily by reheating and soldering.

(2) Method of Soldering

The technique of heating the joint in preparation for soldering was the same as outlined under the method of eutecrod welding. Since the solder requires a lower temperature than eutecrod, the size of the flame used was considerably smaller. The pressure settings on the cylinder regulators were 5 lbs. and 2 lbs. for oxygen and acetylene respectively. The main difference in soldering is when the filler rod is added. As the torch is held in position for heating the joint, it is best to hold the filler rod in the outer fringe of the flame to keep it

[illegible]

in a soft condition. Then, when the reflected flame turns orange, quickly remove the torch and wipe the filler rod along the joint. It will be possible only to run the joint for about 1 to 2 inches, as the metal cools quickly. However, in our method of using the torch to preheat as well as weld, it will be necessary just to heat the joint a second or two until it will be hot enough again to make another run. This procedure is continued until the whole length of weld is completed.

(3) Test Samples and Results (See Figure 13)

A series of tests on samples, similar to those run using eutecrod, were run using solder. Since there is quite a range of temperatures at which the solder will flow and still not affect the parent material, we ran two sample tests. The first was on a model soldered at a very high temperature such that there was almost fusion. The second was run at the lowest possible temperature such that there was no fusion. The results of these two tests were considered as limits of the possible strength a soldered joint would take. In all future tests, we kept our horizontal shear definitely below that indicated by the lowest test.

for a full description. The, which was reflected
from some angles, being some of the best
and also the finest you will find. It
will be possible only to find a few of the
about 1000 copies, for the whole edition
is only 1000. However, in the matter of value
and price to market we will be well off. It will
be necessary just to find the right amount
of two million will be the amount which is
most suitable here. This amount is required
until the whole length of work is completed.
(2) That applies to the whole (the whole of)
A series of books on weights, similar to
those you have mentioned, were not only
needed. These books are quite a range of
subjects and would be of great value to the
authorities and the public alike. The whole of
the series is now being prepared, and will be
of great value to the public. The first one on
the subject of weights is now being prepared
and will be of great value to the public.
The whole of the series is now being prepared
and will be of great value to the public.
The whole of the series is now being prepared
and will be of great value to the public.

Test #1 (Fusion of material and solder noted)

Shear test	a = 1	inch
	L = 2	inches
	b = 3/4	inch
	h = .091	inch

Under a load (P) of 1176 pounds the solder failed in shear

Tension test	a = 1	inch
	b = 3/4	inch
	h = .091	inch

Under a load (P) of 85 pounds, the solder failed.

Test #2 (Low temperature)

Shear test	a = 1	inch
	L = 2	inches
	b = 3/4	inch
	h = .091	inch

The load built up to 50.5 pounds, then the solder yielded suddenly within the joint, although no cracks were visible. It was impossible to make the specimen take any more load. The horizontal shear was 12.6 lbs./inch.

The authors concluded from these tests that if the alladin solder method were to be used it would be necessary to keep the loads down such that the horizontal shear would be less than 12 lbs./inch, except where we were interested in the beam behavior at higher loads.

Test 15 (continued) - continued

Order 15 (continued) - continued
 Order 15 (continued) - continued
 Order 15 (continued) - continued
 Order 15 (continued) - continued
 Order 15 (continued) - continued

Order 15 (continued) - continued

Order 15 (continued) - continued

Order 15 (continued) - continued
 Order 15 (continued) - continued
 Order 15 (continued) - continued
 Order 15 (continued) - continued

Order 15 (continued) - continued

Order 15 (continued) - continued

Test 16 (continued) - continued

Order 16 (continued) - continued
 Order 16 (continued) - continued
 Order 16 (continued) - continued
 Order 16 (continued) - continued
 Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

Order 16 (continued) - continued

(4) Aluminum soldered beam tests and results

Beam #2

Beam #2 was constructed using the alladin solder method in Jig #1. It was tested on the vertical loaded frame.

Dimension of Beam
(See Figure 10)

b = 1.03 inches
t = .064 inches
c = .55 inches
d = 1.16 inches
L = 14 inches

Moment of inertia (I) = .0455

Deflection (D) = $.1256 \times 10^{-3} P$

Stress (f) = 42.3 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
15.1	.600	.5975	.0025	.0019	24.0	640.0
45.75	.600	.5925	.0075	.0057	24.0	1940.0
84.0	.600	.5860	.0140	.0105	25.0	3580.0
100.60	.600	.5835	.0165	.0126	23.6	4260.0
116.35	.600	.5810	.0190	.0146	23.1	4930.0
131.6	.600	.5785	.0215	.0165	23.1	5570.0
156.6	.600	.5742	.0258	.0196	24.0	6640.0
166.35	.600	.5725	.0275	.0209	24.0	7060.0
174.65	.600	.5709	.0291	.0219	24.8	7400.0
188.75	.600	.5684	.0316	.0237	25.0	7999.0
202.75	.600	.5658	.0342	.0255	25.5	8560.0
210.85	.600	.5632	.0368	.0265	27.9	8960.0

The error in Beam #2 was believed to have resulted from the fact that the beam was warped and untrue. We, therefore, constructed beam #3.

Beam #3

Beam #3 was constructed using the alladin soldering method in Jig #1. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.03 inches
t = .064 inch
c = .55 inch
d = 1.15 inches
L = 23 inches

Moment of Inertia (I) = .0452

Deflection (D) = $.558 \times 10^{-3} P$

Stress (f) = 73.2 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.1559	.1568	.0009	.0008	11.0	117.0
5.0	.1554	.1601	.0047	.0028	40.3	366.0
12.2	.1554	.1649	.0095	.0068	28.4	893.0
19.8	.1553	.1692	.0139	.0111	20.1	1455.0
27.8	.1555	.1741	.0186	.0159	15.0	2040.0
35.70	.1556	.1789	.0233	.0199	14.6	2610.0
43.50	.1556	.1839	.0283	.0243	14.2	3190.0
51.25	.1563	.1893	.0330	.0286	13.3	3750.0
58.75	.1575	.1978	.0403	.0328	18.5	4300.0
83.75	.1605	.2440	.0835	.0418	49.3	6130.0

Beam #3 was made considerably longer than Beam #2. This, along with the fact that a zero reading was taken after each load, had a noticeable effect on the results. While these results were better, it was decided to try a new method. We next built beam #5.

When 43 was connected using the classic spinning method in the 41. It was tested on the vertical loading frame.

Dimensions of beam (see Figure 10)
a = 1.0m - length
b = 0.04m - width
c = 0.04m - height
d = 1.1m - distance
e = 0.05m - thickness

Amount of weight (1) = 0.5kg

Deflection (2) = .000 x 10⁻³ m

Stress (3) = 73.4 N

Raw Reading

Load	Defl.	Load	Defl.	Load	Defl.	Load	Defl.
1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00

When 43 was made completely longer than 41. This, along

with the fact that it was reading was taken after each load, and

a noticeable change in the reading. While these results were

being, it was decided to try a new method. An extra hole was 41.

Beam #5

Beam #5 was constructed using the alladin soldering method in Jig #2. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 2.0 inches
t = .091 inches
c = 1.28 inches
d = 2.75 inches
L = 33 inches

Moment of Inertia (I) = .7715

Deflection (D) = $.097 \times 10^{-3} P$

Stress (f) = 13.7 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.09037	.09056	.00019	.00016	15.8	21.9
5.0	.09041	.09110	.00069	.00048	30.4	68.5
13.0	.09041	.09193	.00143	.00126	11.9	178.0
20.5	.09041	.09337	.00296	.00199	32.8	280.0
27.7	.09062	.09395	.00333	.00269	19.2	379.0
34.65	.09041	.09505	.00464	.00336	27.6	473.0
42.50	.09060	.09619	.00559	.00412	26.3	583.0
50.25	.09060	.09752	.00692	.00487	29.6	689.0
58.05	.09081	.09870	.00789	.00563	33.2	795.0
65.20	.09090	.09959	.00869	.00632	27.3	895.0
73.60	.09102	.10071	.00969	.00713	26.7	1010.0
81.90	.09113	.10169	.01056	.00794	24.8	1120.0

Beam #5 was made longer than Beam #3, and of larger section. We made these changes to discover if perhaps length or size of section had a major effect on the results. The irregular results proved nothing other than it didn't appear to be acting as a beam. We next built beam #6.

When the test was conducted using the standard procedure
 tested in 1948. It was noted that the vertical loading

Time:

Dimensions of beam
 (from Figure 10)
 1 = 1.0
 2 = 1.0
 3 = 1.0
 4 = 1.0
 5 = 1.0

Moment of Inertia (I) = 1.0
 Deflection (δ) = 1.0
 Stress (σ) = 1.0

Test Results

Load	Stress	Deflection	Moment	Time	Notes
1.0	0.0007	0.0000	0.0000	10.0	
2.0	0.0014	0.0010	0.0000	20.0	
3.0	0.0021	0.0020	0.0010	30.0	
4.0	0.0028	0.0030	0.0020	40.0	
5.0	0.0035	0.0040	0.0030	50.0	
6.0	0.0042	0.0050	0.0040	60.0	
7.0	0.0049	0.0060	0.0050	70.0	
8.0	0.0056	0.0070	0.0060	80.0	
9.0	0.0063	0.0080	0.0070	90.0	
10.0	0.0070	0.0090	0.0080	100.0	
11.0	0.0077	0.0100	0.0090	110.0	
12.0	0.0084	0.0110	0.0100	120.0	
13.0	0.0091	0.0120	0.0110	130.0	
14.0	0.0098	0.0130	0.0120	140.0	
15.0	0.0105	0.0140	0.0130	150.0	
16.0	0.0112	0.0150	0.0140	160.0	
17.0	0.0119	0.0160	0.0150	170.0	
18.0	0.0126	0.0170	0.0160	180.0	
19.0	0.0133	0.0180	0.0170	190.0	
20.0	0.0140	0.0190	0.0180	200.0	

When the test was conducted using the standard procedure
 tested in 1948. It was noted that the vertical loading
 Time:
 Dimensions of beam
 (from Figure 10)
 1 = 1.0
 2 = 1.0
 3 = 1.0
 4 = 1.0
 5 = 1.0
 Moment of Inertia (I) = 1.0
 Deflection (δ) = 1.0
 Stress (σ) = 1.0
 Test Results
 Load Stress Deflection Moment Time Notes
 1.0 0.0007 0.0000 0.0000 10.0
 2.0 0.0014 0.0010 0.0000 20.0
 3.0 0.0021 0.0020 0.0010 30.0
 4.0 0.0028 0.0030 0.0020 40.0
 5.0 0.0035 0.0040 0.0030 50.0
 6.0 0.0042 0.0050 0.0040 60.0
 7.0 0.0049 0.0060 0.0050 70.0
 8.0 0.0056 0.0070 0.0060 80.0
 9.0 0.0063 0.0080 0.0070 90.0
 10.0 0.0070 0.0090 0.0080 100.0
 11.0 0.0077 0.0100 0.0090 110.0
 12.0 0.0084 0.0110 0.0100 120.0
 13.0 0.0091 0.0120 0.0110 130.0
 14.0 0.0098 0.0130 0.0120 140.0
 15.0 0.0105 0.0140 0.0130 150.0
 16.0 0.0112 0.0150 0.0140 160.0
 17.0 0.0119 0.0160 0.0150 170.0
 18.0 0.0126 0.0170 0.0160 180.0
 19.0 0.0133 0.0180 0.0170 190.0
 20.0 0.0140 0.0190 0.0180 200.0
 We made these tests as a check on the results. The results were
 proved correct after the test was repeated as we used a beam.
 We used this beam for

Beam #6

Beam #6 was constructed using the alladin soldering method in Jig #2. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 2.01 inches
t = .091 inches
c = .96 inches
d = 2.10 inches
L = 26 inches

Moment of Inertia (I) = .424

Deflection (D) = $.0864 \times 10^{-3} P$

Stress (f) = 15.7 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.05533	.05543	.00010	.00014	40.0	25.1
10.0	.05545	.05626	.00081	.00085	4.9	157.0
18.4	.05546	.05645	.00199	.00157	21.1	289.0
25.9	.05550	.05834	.00284	.00221	22.2	407.0
33.65	.05580	.05968	.00388	.00287	26.0	528.0
41.65	.05605	.06040	.00435	.00355	18.4	653.0
48.80	.05608	.06110	.00502	.00417	16.9	765.0
64.55	.05610	.06384	.00774	.00557	28.0	1010.0
73.80	.05665	.06533	.00868	.00636	26.8	1158.0

Beam #6 didn't eliminate the errors although the percentage error was less than that occurring in beam #5.

beam for the construction of the bridge structure
 moved in the air. It was found on the vertical loading
 frame.

Dimensions of beam
 (see Figure 10)

$b = 9.01$ inches
 $t = .061$ inches
 $c = .08$ inches
 $d = 2.10$ inches
 $h = 28$ inches

Moment of inertia (I) = .444

Deflection (δ) = .0001 x 10⁻² p

Stress (σ) = 15.7 p

Test Results

Load	Zero	Load	Def. Def.	Zero Def.	Def. Def.	Stress
1.0	.0000	.0000	.0000	.0000	.0000	15.7
10.0	.0000	.0000	.0000	.0000	.0000	157.0
15.4	.0000	.0000	.0000	.0000	.0000	231.2
22.9	.0000	.0000	.0000	.0000	.0000	407.2
25.25	.0000	.0000	.0000	.0000	.0000	444.2
41.47	.0000	.0000	.0000	.0000	.0000	730.2
48.80	.0000	.0000	.0000	.0000	.0000	864.2
64.22	.0000	.0000	.0000	.0000	.0000	1100.2
73.02	.0000	.0000	.0000	.0000	.0000	1188.0

beam is almost identical the stress although the percentage
 error was less than that occurring in beam 10.

Beam #8

Beam #8 was constructed, using the alladin solder method in Jig #3. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.03 inches
c = .55 inches
d = 1.16 inches
t = .063 inches
L = 24 inches

Moment of inertia (I) = .0454

Deflection (D) = $.634 \times 10^{-3} P$

Stress (f) = 76.7 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.2825	.2835	.001	.00101	1.0	122.5
5.0	.2825	.2857	.0032	.00317	.94	383.0
12.2	.2825	.2912	.0087	.00773	11.5	931.0
19.85	.2825	.2964	.0139	.0126	9.35	1520.0
27.85	.2830	.3023	.0198	.0177	10.60	2130.0
35.70	.2830	.3077	.0247	.0227	8.10	2740.0
43.50	.2833	.3130	.0300	.0276	8.00	3330.0
51.25	.2835	.3183	.0350	.0325	7.13	3930.0
58.75	.2835	.3234	.0399	.0373	6.52	4500.0
65.90	.2835	.3286	.0451	.0408	9.53	5050.0
74.20	.2841	.3341	.0503	.0470	6.50	5680.0
82.35	.2840	.3399	.0558	.0521	6.71	6320.0
90.65	.2847	.3459	.0619	.0575	7.1	6950.0

The percentage error as indicated in beam #8 averages less than 10 percent. This indication that our methods and

TABLE 10

From 48 was constructed, using the standard 1000 ft. scale.

is 17.5. It was found on the vertical 1000 ft. scale.

1 = 100	2 = 100	3 = 100	4 = 100	5 = 100	6 = 100	7 = 100	8 = 100	9 = 100	10 = 100	11 = 100	12 = 100	13 = 100	14 = 100	15 = 100	16 = 100	17 = 100	18 = 100	19 = 100	20 = 100	21 = 100	22 = 100	23 = 100	24 = 100	25 = 100	26 = 100	27 = 100	28 = 100	29 = 100	30 = 100	31 = 100	32 = 100	33 = 100	34 = 100	35 = 100	36 = 100	37 = 100	38 = 100	39 = 100	40 = 100	41 = 100	42 = 100	43 = 100	44 = 100	45 = 100	46 = 100	47 = 100	48 = 100	49 = 100	50 = 100	51 = 100	52 = 100	53 = 100	54 = 100	55 = 100	56 = 100	57 = 100	58 = 100	59 = 100	60 = 100	61 = 100	62 = 100	63 = 100	64 = 100	65 = 100	66 = 100	67 = 100	68 = 100	69 = 100	70 = 100	71 = 100	72 = 100	73 = 100	74 = 100	75 = 100	76 = 100	77 = 100	78 = 100	79 = 100	80 = 100	81 = 100	82 = 100	83 = 100	84 = 100	85 = 100	86 = 100	87 = 100	88 = 100	89 = 100	90 = 100	91 = 100	92 = 100	93 = 100	94 = 100	95 = 100	96 = 100	97 = 100	98 = 100	99 = 100	100 = 100
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Number of insects (1) = 1000

Deflection (2) = 1000 x 1000

From (1) = 1000 x 1000

Load	Time	Loaded	Def. Def.	Comp. Def.	2. Def.	3. Def.
1.0	1.00	1.00	1.00	1.00	1.00	1.00
2.0	2.00	2.00	2.00	2.00	2.00	2.00
3.0	3.00	3.00	3.00	3.00	3.00	3.00
4.0	4.00	4.00	4.00	4.00	4.00	4.00
5.0	5.00	5.00	5.00	5.00	5.00	5.00
6.0	6.00	6.00	6.00	6.00	6.00	6.00
7.0	7.00	7.00	7.00	7.00	7.00	7.00
8.0	8.00	8.00	8.00	8.00	8.00	8.00
9.0	9.00	9.00	9.00	9.00	9.00	9.00
10.0	10.00	10.00	10.00	10.00	10.00	10.00
11.0	11.00	11.00	11.00	11.00	11.00	11.00
12.0	12.00	12.00	12.00	12.00	12.00	12.00
13.0	13.00	13.00	13.00	13.00	13.00	13.00
14.0	14.00	14.00	14.00	14.00	14.00	14.00
15.0	15.00	15.00	15.00	15.00	15.00	15.00
16.0	16.00	16.00	16.00	16.00	16.00	16.00
17.0	17.00	17.00	17.00	17.00	17.00	17.00
18.0	18.00	18.00	18.00	18.00	18.00	18.00
19.0	19.00	19.00	19.00	19.00	19.00	19.00
20.0	20.00	20.00	20.00	20.00	20.00	20.00
21.0	21.00	21.00	21.00	21.00	21.00	21.00
22.0	22.00	22.00	22.00	22.00	22.00	22.00
23.0	23.00	23.00	23.00	23.00	23.00	23.00
24.0	24.00	24.00	24.00	24.00	24.00	24.00
25.0	25.00	25.00	25.00	25.00	25.00	25.00
26.0	26.00	26.00	26.00	26.00	26.00	26.00
27.0	27.00	27.00	27.00	27.00	27.00	27.00
28.0	28.00	28.00	28.00	28.00	28.00	28.00
29.0	29.00	29.00	29.00	29.00	29.00	29.00
30.0	30.00	30.00	30.00	30.00	30.00	30.00
31.0	31.00	31.00	31.00	31.00	31.00	31.00
32.0	32.00	32.00	32.00	32.00	32.00	32.00
33.0	33.00	33.00	33.00	33.00	33.00	33.00
34.0	34.00	34.00	34.00	34.00	34.00	34.00
35.0	35.00	35.00	35.00	35.00	35.00	35.00
36.0	36.00	36.00	36.00	36.00	36.00	36.00
37.0	37.00	37.00	37.00	37.00	37.00	37.00
38.0	38.00	38.00	38.00	38.00	38.00	38.00
39.0	39.00	39.00	39.00	39.00	39.00	39.00
40.0	40.00	40.00	40.00	40.00	40.00	40.00
41.0	41.00	41.00	41.00	41.00	41.00	41.00
42.0	42.00	42.00	42.00	42.00	42.00	42.00
43.0	43.00	43.00	43.00	43.00	43.00	43.00
44.0	44.00	44.00	44.00	44.00	44.00	44.00
45.0	45.00	45.00	45.00	45.00	45.00	45.00
46.0	46.00	46.00	46.00	46.00	46.00	46.00
47.0	47.00	47.00	47.00	47.00	47.00	47.00
48.0	48.00	48.00	48.00	48.00	48.00	48.00
49.0	49.00	49.00	49.00	49.00	49.00	49.00
50.0	50.00	50.00	50.00	50.00	50.00	50.00

The percentage error is indicated in the last column of the table. This indicates that the results are

techniques were improving convinced us that we should continue with our tests with only slight changes in our methods. It should be noticed that the beam is 24 inches long and of such a section that a large deflection is obtained. It is felt that a large deflection is necessary so that any errors that do occur are not a significant part of the deflection. It should also be noted that the horizontal shear on this beam reached 36.2 lbs./inches which is considerably above the absolutely safe value as determined by test. Therefore, in any future tests, a horizontal shear maximum of 10 lbs./inch can be assumed to be absolutely safe. With the above considerations in mind we constructed beam #9.

techniques were improving continuously so that an annual correction
 with our data with slight changes in our system. It
 should be noted that the mean is 94 inches long and at least
 a section that a large deflection is observed. It is clear
 that a large deflection is necessary so that any system that
 do not give out a significant part of the deflection. It
 should also be noted that the horizontal shear on this beam
 would be 25.9 lbs. inches which is considerably above the
 absolutely safe value as determined by test. Therefore, in
 any future tests, a horizontal shear maximum of 12 lbs. inches
 can be assumed to be absolutely safe. With the above consider-
 ations it can be concluded that the

100	100	100	100	100	100	100	100	100	100
90	90	90	90	90	90	90	90	90	90
80	80	80	80	80	80	80	80	80	80
70	70	70	70	70	70	70	70	70	70
60	60	60	60	60	60	60	60	60	60
50	50	50	50	50	50	50	50	50	50
40	40	40	40	40	40	40	40	40	40
30	30	30	30	30	30	30	30	30	30
20	20	20	20	20	20	20	20	20	20
10	10	10	10	10	10	10	10	10	10
0	0	0	0	0	0	0	0	0	0

The following table shows the results of the tests on the various specimens. The first column gives the specimen number, the second column gives the load in pounds, the third column gives the deflection in inches, and the fourth column gives the average value of the deflection in inches.

Beam #9

Beam #9 was a "T" beam constructed using the alladin solder method in Jig #3 modified. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.453 inches
c = .8244 inches
d = 1.0938 inches
t = .091 inches
L = 54 inches

Moment of inertia (I) = .02375

Deflection (D) = $1.38 \times 10^{-2} P$

Stress (f) = 468 P

Horizontal Shear (H) = $\frac{VQ}{I} = .623 P$

The neutral axis was computed to be .268 inches above the base.

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.16340	.18820	.0248	.0221	10.9	747.0
2.0	.16340	.19210	.0287	.0276	3.8	935.0
3.0	.16340	.20710	.0437	.0414	5.24	1405.0
4.0	.16340	.22010	.0567	.0552	2.45	1870.0
5.0	.16340	.23420	.0708	.0690	2.54	2340.0

The error in beam #9 was not as great as that in beam #8. The horizontal shear at 5 lbs. was 3.115 lbs./inches. We stopped loading at 5 lbs. as we wanted to put another flange on the "T" beam to see the effect. Therefore, we soldered a flange on beam #9 to get beam #10.

From the 1970 data, the following values were obtained:

Mean value for the 1970 data: $\bar{y} = 1.000$. It was found that the

variance of the data is:

$$\begin{aligned} \text{Variance of } y &= 1.000 \\ \text{Standard deviation of } y &= 1.000 \\ \text{Mean value of } y &= 1.000 \\ \text{Variance of } y &= 1.000 \\ \text{Standard deviation of } y &= 1.000 \end{aligned}$$

From the 1970 data, the following values were obtained:

Mean value for the 1970 data: $\bar{y} = 1.000$. It was found that the

variance of the data is:

$$\text{Variance of } y = 1.000$$

The variance of the data is 1.000. It was found that the

mean value is:

Mean value:

Year	1970	1971	1972	1973	1974	1975
1.0	1.000	1.000	1.000	1.000	1.000	1.000
2.0	1.000	1.000	1.000	1.000	1.000	1.000
3.0	1.000	1.000	1.000	1.000	1.000	1.000
4.0	1.000	1.000	1.000	1.000	1.000	1.000
5.0	1.000	1.000	1.000	1.000	1.000	1.000

The mean value for the 1970 data is 1.000. It was found that the

variance of the data is 1.000. It was found that the

mean value for the 1970 data is 1.000. It was found that the

variance of the data is 1.000. It was found that the

mean value for the 1970 data is 1.000. It was found that the

Beam #10

Beam #10 is beam #9 with another flange soldered on.

Dimensions of Beam
(See Figure 10)

b = 1.453 inches
c = .548 inches
d = 1.188 inches
t = .091 inches
L = 54 inches

Moment of inertia (I) = .08873

Deflection (D) = 3.7×10^{-3} P

Stress (f) = 90.3 P

Horizontal Shear (H) = .408 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.1320	.1382	.0062	.0059	4.8	144.5
2.0	.1319	.1397	.0078	.0074	5.1	180.5
3.0	.1320	.14285	.01085	.0111	2.3	271.0
4.0	.1320	.1469	.0149	.0148	0.6	361.0
5.0	.1320	.1500	.0180	.0185	2.8	451.0
6.0	.1320	.1541	.0221	.0222	0.4	542.0
7.0	.1320	.1580	.0260	.0259	0.4	631.0
8.0	.1320	.1620	.0300	.0296	1.3	722.0
9.0	.1320	.1658	.0338	.0333	1.5	811.0
10.0	.1320	.1697	.0377	.0370	1.9	903.0
18.0	.1321	.1998	.0678	.0666	1.8	1628.0

The small amount of difference between computed and actual deflections as evidenced by the percentage error was considered excellent. The horizontal shear obtained was 7.35 lbs./inches at 18 lbs. In view of the results, it was decided to construct a beam of larger cross section, to see if there would be any effect on the accuracy.

FOIA b(7)(C) - Disclosure would reveal information from a confidential source.

1968	1.00	=	1		
1967	1.00	=	2		
1966	1.00	=	3		
1965	1.00	=	4		
1964	1.00	=	5		
1963	1.00	=	6		
1962	1.00	=	7		
1961	1.00	=	8		
1960	1.00	=	9		
1959	1.00	=	10		
1958	1.00	=	11		
1957	1.00	=	12		
1956	1.00	=	13		
1955	1.00	=	14		
1954	1.00	=	15		
1953	1.00	=	16		
1952	1.00	=	17		
1951	1.00	=	18		
1950	1.00	=	19		
1949	1.00	=	20		
1948	1.00	=	21		
1947	1.00	=	22		
1946	1.00	=	23		
1945	1.00	=	24		
1944	1.00	=	25		
1943	1.00	=	26		
1942	1.00	=	27		
1941	1.00	=	28		
1940	1.00	=	29		
1939	1.00	=	30		
1938	1.00	=	31		
1937	1.00	=	32		
1936	1.00	=	33		
1935	1.00	=	34		
1934	1.00	=	35		
1933	1.00	=	36		
1932	1.00	=	37		
1931	1.00	=	38		
1930	1.00	=	39		
1929	1.00	=	40		
1928	1.00	=	41		
1927	1.00	=	42		
1926	1.00	=	43		
1925	1.00	=	44		
1924	1.00	=	45		
1923	1.00	=	46		
1922	1.00	=	47		
1921	1.00	=	48		
1920	1.00	=	49		
1919	1.00	=	50		
1918	1.00	=	51		
1917	1.00	=	52		
1916	1.00	=	53		
1915	1.00	=	54		
1914	1.00	=	55		
1913	1.00	=	56		
1912	1.00	=	57		
1911	1.00	=	58		
1910	1.00	=	59		
1909	1.00	=	60		
1908	1.00	=	61		
1907	1.00	=	62		
1906	1.00	=	63		
1905	1.00	=	64		
1904	1.00	=	65		
1903	1.00	=	66		
1902	1.00	=	67		
1901	1.00	=	68		
1900	1.00	=	69		
1899	1.00	=	70		
1898	1.00	=	71		
1897	1.00	=	72		
1896	1.00	=	73		
1895	1.00	=	74		
1894	1.00	=	75		
1893	1.00	=	76		
1892	1.00	=	77		
1891	1.00	=	78		
1890	1.00	=	79		
1889	1.00	=	80		
1888	1.00	=	81		
1887	1.00	=	82		
1886	1.00	=	83		
1885	1.00	=	84		
1884	1.00	=	85		
1883	1.00	=	86		
1882	1.00	=	87		
1881	1.00	=	88		
1880	1.00	=	89		
1879	1.00	=	90		
1878	1.00	=	91		
1877	1.00	=	92		
1876	1.00	=	93		
1875	1.00	=	94		
1874	1.00	=	95		
1873	1.00	=	96		
1872	1.00	=	97		
1871	1.00	=	98		
1870	1.00	=	99		
1869	1.00	=	100		

1975, p. 1) and is also

5. $\delta_{01} \approx 5.2 \times 10^{-4}$ (7) calculated

1. 2, 0, 0 = (1) mixed

[illegible]

The small amount of literature published in 1951
has been an indication of the progress of the work and has
been a source of information to the public. The National
Academy of Sciences, in its report, has stated that the
work of the Committee has been of great value to the
country and that it has been a source of information to
the public.

Beam #11

Beam #11 was constructed using the alladin solder method in Jig #3 modified. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.234 inches
c = 1.193 inches
d = 2.477 inches
t = .091 inches
L = 54 inches

Moment of Inertia (I) = .4128

Deflection (D) = $.798 \times 10^{-3}$ P

Stress (f) = 40.5 P

Horizontal Shear (H) = .1623 P

Dial Reading						
Load	Zero	Loaded	Act. Def.	Comp. Def.	% Diff.	Stress
5	.0964	.1001	.0037	.0040	8.1	202.0
10	.0965	.1041	.0076	.0080	5.3	404.0
15	.0965	.1083	.0118	.0120	1.7	616.0
20	.0965	.1122	.0157	.0160	1.9	807.0
25	.0965	.1164	.0199	.0199	0.0	1015.0
30	.0967	.1208	.0243	.0239	1.6	1215.0
35	.0967	.1250	.0283	.0279	1.4	1417.0
40	.0967	.1290	.0323	.0319	1.2	1620.0
45	.0968	.1333	.0366	.0359	1.9	1823.0
50	.0969	.1380	.0412	.0399	3.2	2020.0
55	.0969	.1419	.0450	.0439	2.4	2230.0

The results of Beam #11 proved that our methods and techniques of constructing models were satisfactory. This beam was made with the idea in mind of using it for checking stresses and calibrating the horizontal loading frame. (See Figure 14.) These tests are explained in section IV.

These will be conducted under the following conditions:

Approved for release by NSA on 08-28-2013 pursuant to E.O. 13526

1992

Distance of Run	Time	Speed
1.000	1.000	1.000
1.100	1.100	1.100
1.200	1.200	1.200
1.300	1.300	1.300
1.400	1.400	1.400
1.500	1.500	1.500
1.600	1.600	1.600
1.700	1.700	1.700
1.800	1.800	1.800
1.900	1.900	1.900
2.000	2.000	2.000

2512. = (1) altered to 200000

5. $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (acid-base)

С. В. Ов. 23 (2) 1980

1995, p. 111) (1995, p. 111)

[illegible]

The results of these will provide more detailed and reliable
evidence of continuing economic growth. This has been
made with the idea in mind of being in the economic progress and
utilizing the historical records. (See Figure 10.)
These results are available in section IV.

Beam #11 on Horizontal
Loading Frame

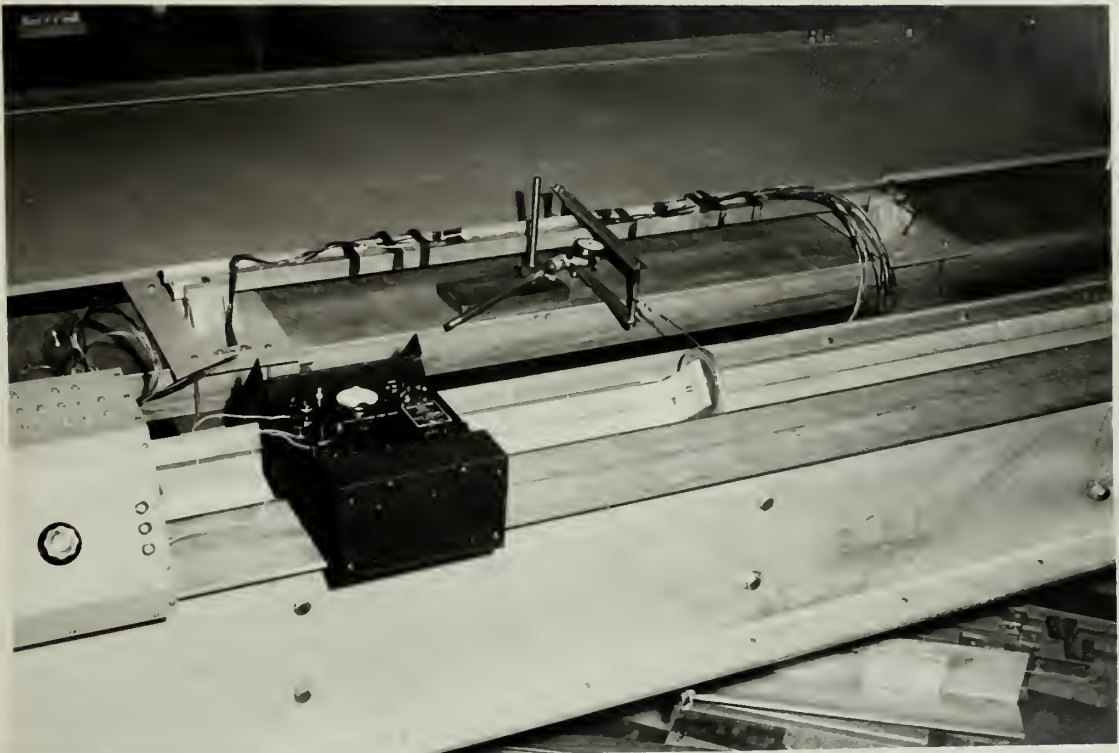
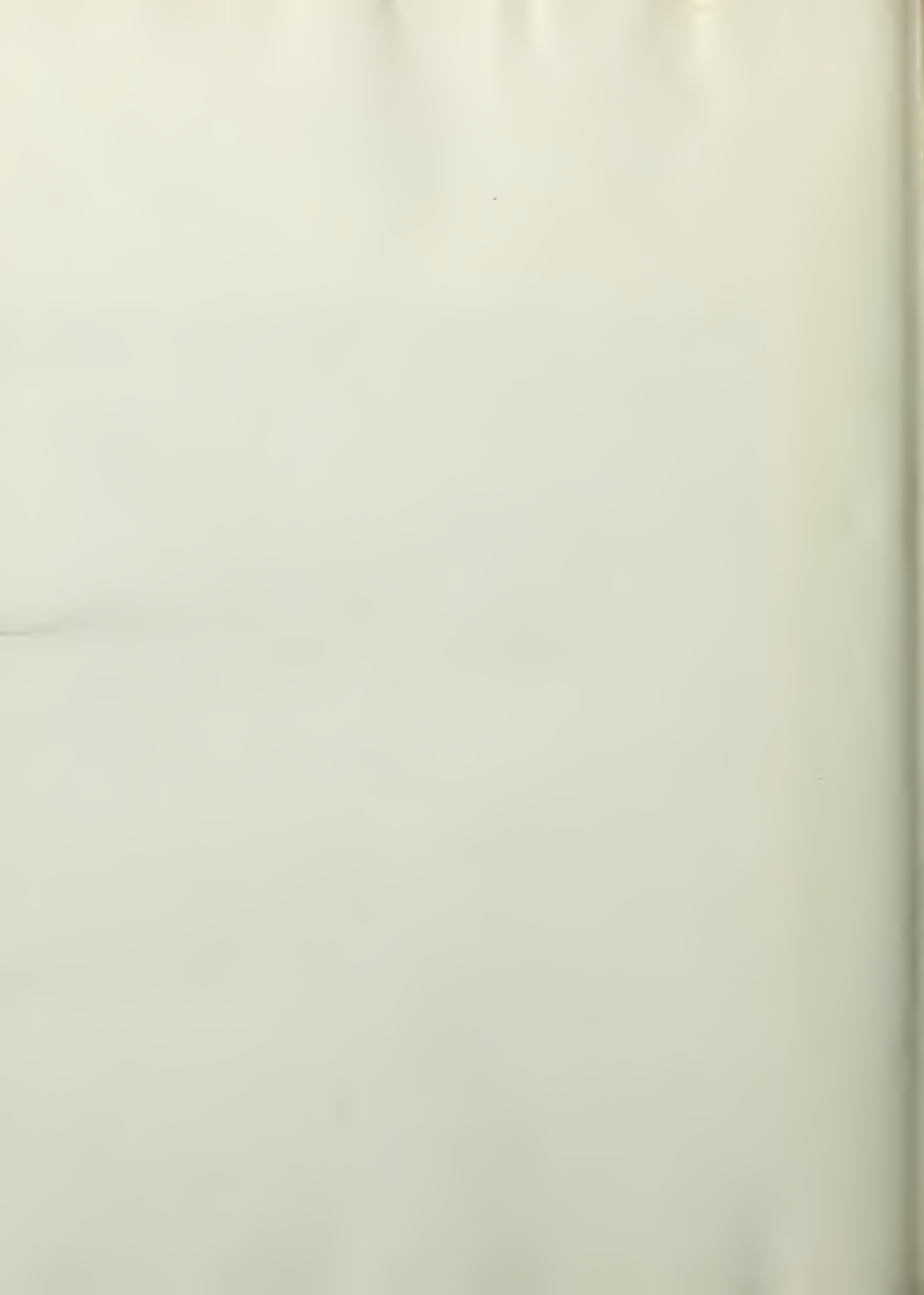


Figure 14



c. Furnace Brazing

The third method of constructing beams by furnace brazing was not successful. The furnace used was the same one that was mentioned in the "E" check discussion.

The beam constructed was 24 inches long, 1-1/2 inches deep, .091 inches thick and the flanges were 1-1/4 inches wide. The beam was held together in the manner discussed for Jig #3 modified, with clamps holding the flanges together. The joining material used was eutecrod. In order to get a thin foil, the eutecrod was rolled to a thickness of about .008 inches. It was inserted in the joint and held in place by the clamping action of the "C" clamps. Flux was placed along all the surfaces that were to be joined. The furnace temperature used was 1125° F. This was the temperature, found from tests, that was necessary for the materials to fuze. The jugged beam was placed in the furnace and allowed to remain for 15 minutes. At the end of the required time, the furnace was shut off and allowed to cool before inspecting the beam.

The whole beam was completely distorted and warped. (See Figure 15.) The flanges were welded to the web for only about 2 inches at one end. It was impossible to test the beam because of its condition.

63
The third method of connecting beams by
Lutrope hydraulic was not successful. The Lutrope used
was the same one that was mentioned in the
check dissection.

The beam dissection was 34 inches long, 1-1/8
inches deep, .031 inches thick and the
were 1-1/4 inches wide. The beam was held in
together in the manner described for the
with almost holding the pieces together. The
joining material used was subjected. In order to
get a thin foil, the subjected was rolled to a
thickness of .001 inches. It was inserted
in the joint and held in place by the
section of the "C" channel. The was placed along
all the surfaces and was to be removed. The
Lutrope temperature used was 1150° F. This was
the temperature, found from tests, that was
necessary for the material to fuse. The
beam was placed in the Lutrope and allowed to
remain for 15 minutes. At the end of the
time, the Lutrope was shut off and allowed to
cool before inspecting the beam.

The whole beam was completely disassembled and
removed. (See Figure 12.) The Lutrope was held
so as to see for only about 2 inches at one end.
It was impossible to see the beam because of its
condition.

Furnace Brazed Aluminum Beam



Figure 15



This method is impractical for use with aluminum. The eutecrod will not flow by itself until a temperature of about 1125° F. is reached. This temperature is above the melting point of the alloy used, and the beam will not even support its own weight. Thus, with the jiggling system used, the weight of the clamps alone caused the whole beam to be pulled out of shape. Therefore, the authors felt it a waste of time to attempt any further tests.

B. Steel.

For the fabrication of steel models, we selected hot rolled strip steel, 1-1/2 inches wide and 0.056 inches thick. This particular size material was selected from the available stock at a local steel yard because it would require the least cutting in the fabrication of a model. Hot rolled strip was chosen in preference to cold rolled strip because of its being relatively free of residual stresses.

1. Preparation of Material

A hacksaw was used to cut the strip steel into the desired lengths. The rounded edges of the pieces were ground flat on a mechanical disc sander. Next, the scale on the edges and sides, where the pieces were to be joined, was removed by using emery cloth which gave a bright surface. Care should be exercised in grinding the edges to insure that a smooth, flat surface is obtained. Irregularities will cause a poor joint.

This method is unsatisfactory for use at 25
 atmospheres. The material will not flow by itself
 until a temperature of about 1150° F. is reached.
 This temperature is above the melting point of
 the alloy used, and the same will not even support
 its own weight. Thus, with the liquid system
 used, the weight of the clamps about caused the
 metal to be pulled out of shape. Therefore,
 the authors felt it a waste of time to attempt
 any further tests.

2. Steel.

For the fabrication of steel samples, as indicated by
 rolled strip steel, 1-1/2 inches wide and 0.005 inches thick.
 This particular size material was selected from the available
 stock of a local steel yard because it was available in
 least quantity in the fabrication of a model. The rolled
 strip was chosen in preference to cold rolled strip because
 of its better mechanical properties of uniformity.

1. Preparation of material

A thickness was used for the strip steel into
 the desired length. The thickness of the plates was
 found 1/2 in a mechanical size tester. Next, the ends of
 the edges and sharp corners the plates were to be joined, was
 removed by using heavy files which gave a smooth surface.
 These should be exercised in grinding the edges to insure that
 a smooth, flat surface is obtained. Investigations will
 cause a poor joint.

2. Jigs

Jigs used for making steel models were the same as those used for making aluminum models, as given in section III-A-2 above; consequently, they need not be discussed again in this section.

3. Techniques of Joining Flanges to Webs

a. Silver soldering with an oxyacetylene torch

In joining the pieces of steel together to form a model, we wanted a strong joint, which could be obtained without heating the steel into its critical range. Heating to a low temperature was desirable also to avoid large expansions and accompanying distortions. Silver soldering seemed to possess all of the above desirable characteristics. The "Easy Flow" solder we used flowed freely at 1175° F., which is well below steel's critical temperature, and it possessed a tensile strength of approximately 65,000 psi.

(1) Joint thickness

In the "Welding Handbook" of the American Welding Society, a graph is shown expressing the strength of a soldered butt joint, using silver solder to join stainless steel, as a function of the joint thickness. With a joint thickness of 0.003 inches, the joint strength was 117,000 psi, while with a

thickness of 0.024 inches, the strength was 47,000 psi. This shows the desirability of having a close fitting joint between the pieces being joined.

(2) Heating and fluxing

Before the joint was heated, a coating of flux* was painted on the surfaces to be joined, its purpose being to prevent oxidation of the solder and steel surfaces being joined, to dissolve any oxides that might form during heating, and to assist the flowing of the alloy. The flux also serves as a temperature indicator, in that the joint should be heated until the flux remains fluid if the torch flame is removed for an instant.

The models we made consisted of tee and wide-flange sections. In joining the web to the flange, the torch was held in a position so that the flame (a slightly reducing flame was used) was approximately parallel to the axis of the joint being soldered. (See Figure 12.) By directing the flame in this manner, the material in the vicinity of the torch tip was heated to the soldering temperature,

* A Borax and Boric Acid mixture.

75,000,000. The amount of the loan is \$75,000,000.

...and a large number of other persons.

... (b) ...

Before the Joint was tested, a condition

[illegible][illegible]

[Faint, illegible text]

[illegible]

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

...and the ...

100-443887-100

The models we made consisted of 140

44. 2001年10月1日，甲企业向乙企业借入期限为3个月的借款100000元，年利率为6%。甲企业于2002年1月1日偿还该笔借款。甲企业应确认的利息费用为（ ）元。

1997-1998

1980

It is not clear that the above information is relevant to the case.

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

while the material away from the torch tip in the direction of the flame became preheated to a relatively high temperature. When the correct temperature was reached, as indicated by the fluid flux, the silver solder rod was touched to the joint. The solder flowed freely along the joint until the joint became too cool. By moving the torch slowly and applying solder from the rod at about every inch, a strong joint was obtained throughout the length of the pieces.

If the joint is dirty, or if the flux is rubbed off at a point along the joint, no amount of heating will cause the solder to adhere to the pieces. In this event, wait until the pieces cool, clean and reflux the spot, then reheat and solder it.

(3) Test samples and results

In order to check the strength of the silver solder joint in shear and tension, test samples of joints were prepared and tested. (See Figure 13.)

Shear test

a = 1 inch
L = 1 inch
b = 3/4 inch
h = .056 inch

Tension test

a = 1 inch
b = 1 inch
h = .056 inch

Two inches of joint tested in shear was

stronger than the parent metal, while one inch tested in tension broke at 2830 pounds. The strength of the joint was seen to be more than sufficient for our purposes.

REMARKS: The above is a copy of the original
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now in the hands of the original.

(4) Beam tests and results

Beam #12

Beam #12 was a "T" beam constructed by using silver solder rod and an oxyactelylene torch, in Jig #2. It was tested on the vertical loading frame with the results as given below:

Dimensions of beam
(See Figure 10)

b = 1.5 inches
t = .056 inches
d = 1.56 inches
L = 22 inches

The neutral axis was computed to be .417 inches above the base.

Moment of Inertia (I) = .0905

Deflection (D) = .0817 P x 10⁻³

Stress (f) = 69.3 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.4107	.4132	.0015	.00082	83.0	690.0
25	.4110	.4141	.0031	.00204	52.0	1735.0
50	.4110	.4170	.0060	.00408	47.0	3470.0
75	.4107	.4186	.0089	.00612	45.5	5200.0
100	.4108	.4220	.0112	.00817	37.1	6930.0
125	.4110	.4242	.0132	.01020	29.4	8670.0
150	.4111	.4259	.0148	.01223	21.0	10400.0

This beam was distorted from heating. The web was not exactly centered on the flange. The joint, however, appeared to be very good.

b. Furnace Brazing (See Figure 16)

In an effort to overcome the distortion of the material being joined resulting from localized heating with a torch, furnace brazing was tried. The bonding alloy was silver solder, in the form of a thin foil or sheet 0.005 inches thick. The pieces to be joined were prepared as stated in section III-A-1. Flux was applied to the surfaces for the purpose previously stated. Finally, strips of the foil were inserted in the joint between the pieces to be united, and the whole assembly clamped rigidly together. The pieces could be clamped rigidly together since there would be no differential expansion between the model components while in the furnace. The assembly was then inserted in the furnace.

(1) The furnace

The furnace used was a Lindberg type, belonging to the Metallurgy Department. It was an automatically controlled, electric furnace, equipped with a blower for circulating the air within it. Prior to inserting the model, the temperature was raised to 1175° F.

The model was left in the furnace for 15 minutes at the 1175° temperature, then

Furnace Brazed Steel Beam



Figure 16

taken out and allowed to cool in air.

(2) Patching the model

The model referred to in the above paragraph was a wide-flange section, about 22 inches long. Near one end, the flange was not joined to the web for a distance of about 2 inches. It is presumed that this bad joint was caused by an uneven web which allowed too large an opening to be filled by the solder. This spot was patched by placing another strip of foil in the opening, fluxing it, and reheating the area with a torch.

See following pages for the results of the testing of these models.

taken out and allowed to cool in air.

(2) Patching the model

The model referred to in the above paragraph was a wide-flange section, about 22 inches long. Near one end, the flange was not joined to the web for a distance of about 2 inches. It is presumed that this bad joint was caused by an uneven web which allowed too large an opening to be filled by the solder. This spot was patched by placing another strip of foil in the opening, fluxing it, and reheating the area with a torch.

See following pages for the results of the testing of these models.

It was not allowed to come in at all.

(2) The second was as follows:

The second referred to in the above was-

There was a wide-brimmed hat, about 18

inches long. It was not a hat, but a piece of

not joined at the top for a distance of about

18 inches. It is supposed that this was joined

was caused by an injury and was not a hat.

Two days or more it is said to be killed by the

soldier. This was not joined up at all.

Another story of this is the opening. Finding

it, and following the line with a torch.

See following page for the results of

the test of this matter.

(3) Beam test and results

Beam #13

Beam #13 was a "T" beam fabricated by furnace brazing with silver solder using Jig #3 modified, and clamping the pieces rigidly together with "C" clamps. It was tested on the vertical loading frame with the following results.

Dimensions of Beam	b = 1.5 inches
(See Figure 10)	t = .056 inches
	d = 1.56 inches
	L = 16 inches

The neutral axis was computed to be .417 inches above the base.

Moment of Inertia (I) = .0905

Deflection (D) = .0315 P x 10⁻³

Stress (f) = 50.4 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.1520	.1476	.0044	.00315	28.5	504.0
35	.1581	.1478	.0103	.0110	6.8	1765.0
60	.1600	.1478	.0122	.0890	55.0	3030.0

The erratic results were thought to have been caused by buckling of the web as the load was applied. The beam showed very little distortion, and the joint appeared sound.

(33-35-10-1) and 35-35-10-2

Form 113

Form 113 was used to record the following data:

The water table was measured at 10, 25, and 50 feet below the surface.

The water table was measured at 10, 25, and 50 feet below the surface.

The water table was measured at 10, 25, and 50 feet below the surface.

Observations of water table (see Figure 10)

1 = 10 feet
2 = 25 feet
3 = 50 feet

The water table was measured at 10, 25, and 50 feet below the surface.

The data.

Water table (1) = 10.000

Water table (2) = 10.000 & 10.000

Water table (3) = 10.000

Load	Water	Water	Water	Water	Water	Water
10	10.000	10.000	10.000	10.000	10.000	10.000
25	10.000	10.000	10.000	10.000	10.000	10.000
50	10.000	10.000	10.000	10.000	10.000	10.000

The water table was measured at 10, 25, and 50 feet below the surface.

The water table was measured at 10, 25, and 50 feet below the surface.

The water table was measured at 10, 25, and 50 feet below the surface.

Beam #14

Beam #14 was a wide flange section which was furnace brazed using silver solder. Jigging method #3 modified, with the assembly clamped rigidly together, was used.

Dimensions of Beam
(See Figure 10)

b = 1.5 inches
t = .056 inches
d = 1.61 inches
L = 22 inches

Moment of Inertia (I) = .1172

Deflection (D) = .0631 P x 10⁻³

Stress (f) = 37.8 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
110	.18440	.19490	.0150	.00695	33.8	4160.0
185	.18450	.20180	.01730	.01169	32.0	6990.0
60	.18530	.19130	.00600	.00380	36.5	2270.0

This beam appeared to be distortion free and unwarped throughout its length. The joint, after it was patched, appeared to be satisfactory. The cause of the bad test results could be attributed only to the imperfect joint, which, even after being patched, probably was not strong enough.

There was a wide variety of specimens which were collected.

Specimens of the same species were collected in different localities.

With the exception of the specimens collected in the same locality, the specimens were collected in different localities.

Dimensions of head	1.5	1.5	1.5	1.5	1.5	1.5
(from right eye)	1.5	1.5	1.5	1.5	1.5	1.5
	1.5	1.5	1.5	1.5	1.5	1.5
	1.5	1.5	1.5	1.5	1.5	1.5
	1.5	1.5	1.5	1.5	1.5	1.5
	1.5	1.5	1.5	1.5	1.5	1.5

Dimensions of head (1) = 1.5

Dimensions of head (2) = 1.5

Dimensions of head (3) = 1.5

Head	Body	Length	Weight	Age	Sex	Notes
110	1.5	1.5	1.5	1.5	1.5	1.5
188	1.5	1.5	1.5	1.5	1.5	1.5
60	1.5	1.5	1.5	1.5	1.5	1.5

This specimen appeared to be different from the others.

Dimensions of head (1) = 1.5, (2) = 1.5, (3) = 1.5.

Dimensions of head (4) = 1.5, (5) = 1.5, (6) = 1.5.

Dimensions of head (7) = 1.5, (8) = 1.5, (9) = 1.5.

Dimensions of head (10) = 1.5, (11) = 1.5, (12) = 1.5.

Dimensions of head (13) = 1.5.

Types of Beams Constructed



Figure 17

IV. Check of Beam #11 by Electric Strain Gages

Beam #11 was found to be very satisfactory when loaded on the vertical loading frame. The average variation between the computed and actual deflections of this model under load was less than two percent. It could be presumed, then, that as a whole the model was acting as a wide-flange beam should. However, in order to check this beam further and in particular to find out something about the stress distribution at various sections along its length, several SR-4 electric strain gages were mounted on it.

A. Location of Gages

A total of 11 gages were mounted on the web and flange of the beam as shown in Figure 18. Gages #1 and #4 were located at a distance of one beam depth away from the centerline of the beam, where the load was applied. According to the St. Venant principle, the stress at this section should be as given by the elastic theory. Gages #2, #3, #5, #6, and #7 were placed at a distance of three beam depths away from the load on one side of the mid-point while gages #8, #9, #10, and #11 were placed at a like distance on the other side of the mid-point. By locating the gages at these sections and placing some on the flange and others at different distances from the neutral axis on the web, we attempted to obtain a representative set of stress values.

B. Loading and Results

As stated previously, this beam had already been checked on the vertical loading frame. Since it was antici-

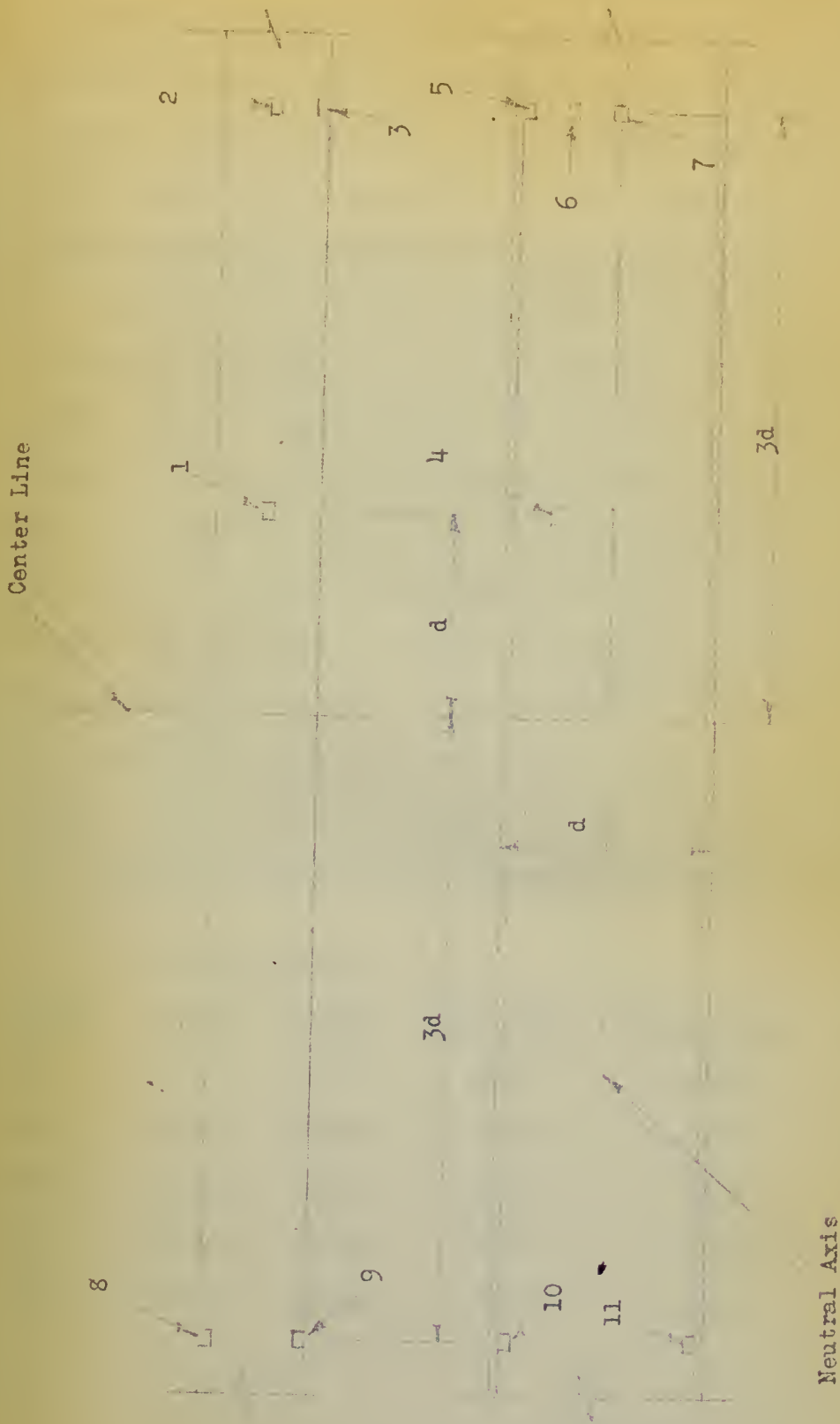
Beam size was found to be very satisfactory when located on the vertical loading frame. The electric field was measured between the electrodes and actual dimensions of beam model under load was found to be two percent. It could be presumed, then, that as a whole the model was acting as a wide-flange beam. However, in order to obtain this beam behavior and in particular to find out something about the electric distribution at various sections along the length, several 1/8" x 1/8" electric strain gages were mounted on it.

A. Location of Gages

A total of 11 gages were mounted on the top and flange of the beam as shown in Figure 10. Gages 1 and 2 were located at a distance of one inch from each other at the centerline of the beam, where the load was applied. Gages 3 and 4 were located at the 1/4" vertical distance, the same as the vertical distance between the electric strain gages. Gages 5, 6, 7, 8, 9, 10, and 11 were placed at a distance of three inch from the top flange on one side of the mid-point while gages 12, 13, 14, and 15 were placed at a like distance on the other side of the mid-point. By locating the gages at these sections and placing some on the top and others at different distances from the central axis on the top, we attempted to obtain a representative set of stress values.

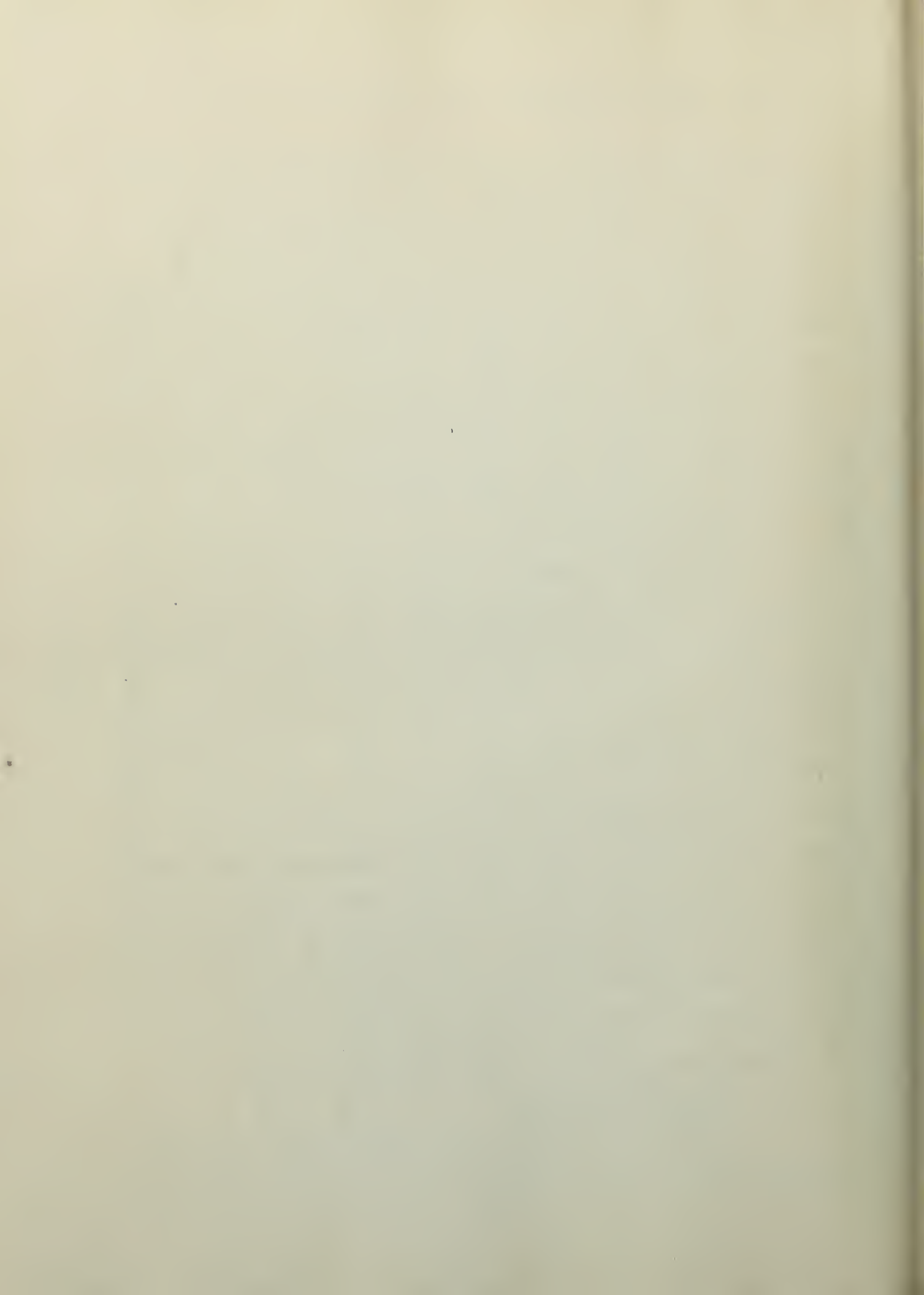
B. Loading and Results

As stated previously, this beam had already been checked on the vertical loading frame. Figure 11 was used to



Alladin Soldered Beam # 11, Showing Strain Gage Location

Figure 18



pated that models made by our technique would be tested eventually on the horizontal loading frame, it was necessary first of all to check the action of the horizontal loading frame. (See Figure 19.) It was feared that there would be some friction losses caused by the change in direction of application of the load over a pulley.

Beam #11 was placed upon the loading frame in a horizontal position with steel ball bearings, sandwiched between glass plates, supporting it. (See Figure 14.) The same loading yoke that was used for vertical loading was supported at the center of the beam on ball bearings. The flanges at the end of the beam were pushed snugly against the vertical knife edge supports, making sure that the flanges were bearing along their whole length against the knife edges. A load of known value was applied, then, at the end of a steel cable, which passed over the pulley and was attached to the yoke. The results of this loading are shown below:

Dial Reading						
<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.0745	.0826	.0081	.0080	1.25	405.0
20	.0745	.0900	.0155	.0160	3.1	810.0
30	.0745	.0979	.0234	.0240	2.5	1215.0
40	.0745	.1058	.0313	.0320	2.2	1620.0
50	.0745	.1138	.0393	.0400	1.75	2025.0

tested these models made up of sand which would be tested eventually on the horizontal loading frame, it was necessary first of all to check the action of the horizontal loading frame. (See Figure 12.) It was tested first there would be some friction losses caused by the change in direction of application of the load over a pulley.

When this was placed upon the loading frame in a horizontal position with steel ball bearings, interposed between glass plates, supporting it. (See Figure 14.) The same loading frame that was used for vertical loading was supported at the center of the beam on ball bearings. The flanges at the end of the beam were loaded roughly against the vertical knife edge supports, which were that the flanges were being along their whole length against the knife edges. A load of known value was applied, then, at the end of a steel cable which passed over the pulley and was attached to the yoke.

The results of this loading are shown below:

Steel Loading						
Load	Yoke	Loaded	App. Cal.	Temp. Cal.	# Grits	Stress
10	.0788	.0888	.0081	.0080	1.84	408.0
20	.0788	.0900	.0180	.0180	2.1	810.0
30	.0788	.0978	.0284	.0280	2.8	1218.0
40	.0788	.1088	.0388	.0380	3.8	1620.0
50	.0788	.1188	.0388	.0400	1.75	2025.0

Horizontal Loading Frame



Figure 19

A comparison of the actual and computed deflections shows that the friction losses are negligible since the actual differences are no greater than those occurring with vertical loading. These encouraging results showed that the horizontal loading frame, with all of its advantages in accommodating large models and in the case of applying diversified loads, could be used for future tests.

Leads from the SR-4 gages were connected with the indicating device, and values of strains read for different loads. The results of these loadings are shown on the next few pages.

A comparison of the actual and expected inflation rates

that the typical loader was available since the actual differences are so great that these occurring with various loading. These differences were shown that the difference in loading times, with all of the differences in accommodating large models and in the case of applying standard loads, could be used for future tests.

The results of these loadings are shown on the next two pages. Setting devices, and values of device used for different loads. Leads from the 10-4 leads were connected with the 10-5

Form of Computations for Stresses at Various Sections Along
Beam #11

Computations:

Section at "d" distance from the center (See Figure 18)

$$M = \left(\frac{P}{2}\right) (24.5) = 12.25 P \quad I = .4128$$

$$\text{Computed } f = \frac{Mc}{I} = \frac{(12.25 P)(c)}{.4128} = 29.6 Pc$$

$$\text{Actual } f = eE = e \times 10^{-7}$$

Section at 3 "d" distance from the center

$$M = \left(\frac{P}{2}\right) (19.56) = 9.78 P$$

$$\text{Computed } f = \frac{Mc}{I} = \frac{(9.78 P)(c)}{.4128} = 23.7 Pc$$

$$\text{Actual } f = eE = e \times 10^{-7}$$

Terms Defined:

I, moment of inertia, inches⁴

M, bending moment, inch lbs.

P, load, lbs.

f, stress, lbs./inch²

c, distance from neutral axis of beam to center of gage

e, strain indicated by SR-4 gage, micro-inches/inch

E, modulus of elasticity of aluminum, lbs./inch²

Values of c:

gage 1, 1.238	gage 5, .88	gage 9, 1.238
gage 2, 1.238	gage 6, .45	gage 10, .88
gage 3, 1.238	gage 7, 0	gage 11, .93
gage 4, .47	gage 8, 1.238	

P = 10 lbs.

Gage	1	2	3	4	5	6	7	8	9	10	11
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0598	0091	0709	1887	0350	1351	1452	1022	1860	0779	0273
e	24	22	23	13	20	10	1	30	24	19	13
Act. f	240	220	230	130	200	100	10	300	240	190	130
Comp. f	367	293	293	138	207	106	0	293	293	209	220
% Diff.	34.5	24.9	21.5	5.8	3.4	5.7		2.4	18.1	9.0	41.0

P = 20 lbs.

Gage	1	2	3	4	5	6	7	8	9	10	11
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0561	0064	0686	1871	0332	1340	1454	0998	1835	0761	0288
e	61	49	46	29	38	21	1	54	49	37	28
Act. f	610	490	460	290	380	210	10	540	490	370	280
Comp. f	735	587	587	277	415	213	0	588	588	417	441
% Diff.	17.0	16.5	21.7	4.7	8.5	1.4		8.2	16.7	11.2	36.4

P = 30 lbs.

Gage	1	2	3	4	5	6	7	8	9	10	11
Zero	0622	0113	0732	1900	0370	1361	1455	1052	1884	0798	0260
Loaded	0529	0035	0662	1858	0312	1328	1453	0968	1808	0743	0300
e	93	78	70	42	58	33	2	84	76	55	40
Act. f	930	780	700	420	580	330	20	840	760	550	400
Comp. f	1100	880	880	417	625	320	0	881	881	626	662
% Diff.	15.5	11.3	13.6	0.7	7.2	3.1		4.6	13.7	12.1	39.7

[illegible]

4010 50 100

[illegible]

1000 1000 1000

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412
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P = 40 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0498	0009	0640	1840	0292	1317	1452	1022	1860	0779	0273
e	124	104	92	60	78	44	1	30	24	19	13
Act. f	1240	1040	920	600	780	440	10	300	240	190	130
Comp. f	1470	1175	1175	555	831	426	0	293	293	209	220
% Diff.	15.6	11.5	21.7	8.1	6.1	3.3		2.4	18.1	9.0	41.0

P = 50 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0624	2115	0731	1900	0564	1355	1451	1052	1884	0798	0260
Loaded	0461	1984	0620	1829	0273	1301	1449	0906	1763	0709	0329
e	163	131	111	71	91	54	2	146	121	89	69
Act. f	1630	1310	1110	710	910	540	20	1460	1210	890	690
Comp. f	1838	1470	1470	695	1040	533	0	1470	1470	1442	1102
% Diff.	11.3	10.9	24.5	2.2	12.5	1.3		0.7	17.6	14.6	37.5

[illegible][illegible]

C. Conclusions

In general, the difference between the computed and actual values of stress becomes less as the load is increased. This indicates that for higher stresses, errors introduced by slight inaccuracies in construction have reduced effect. The difference between values of stress indicated by gages 2 and 3 shows that the edge of the flange participates less in resisting the load than the center of the flange. This was probably due to a slight buckling of the flange at its outer edge. Gages 4 and 6, which were located on the web midway between the neutral axis and the flange, gave consistently good results. This was due, it was thought, to their location away from the point where the web and flange were joined. Gages 5 and 10, located on the web near the flange, gave good results, but a little less accurately than gages 4 and 6. The difference between stresses at gages 8 and 9 was caused by the knife edge of the loading yoke not bearing evenly across the top flange. This caused one side of the flange to assume more load than the other. No reason can be given for the large discrepancy between the computed and actual stresses given by gage 11, unless it was due to a defective gage.

An overall comparison of computed and actual stresses indicated that the model was acting satisfactorily. The stress distribution closely approximated that given by the flexural theory.

V. Constructing and Testing a Rigid Frame

The construction and testing of a rigid frame was considered as the culmination of all the work done on this thesis. A rigid frame is one that is constructed to resist moment at the joints. The method of building a joint to resist moment may be either by riveting or welding. It is in this section that we discuss how we constructed and tested a welded rigid frame.

A. Purpose

The task of constructing a rigid frame was undertaken for two main reasons. The first, and most important to us, was to investigate the soundness of our techniques and methods in building models other than plain straight beams. Our last tests of beams were very successful, however, the beams were all of the same design. Thus, in order to be certain that the techniques and methods were sound, we built the rigid frame as shown in Figure 20. It would have been possible to construct a differently shaped model to test, but it was for the reason mentioned below that made us decide in favor of a rigid frame. As evidenced by the tests run on rigid frames, as mentioned in the introduction, there was still much to be learned, particularly about the stresses at the knees. Therefore, by building a rigid frame, we hoped not only to prove that our techniques were sound, but also to advance, perhaps, the understanding of stresses at knees in rigid frames.

B. Design

The design of the frame was not completely an

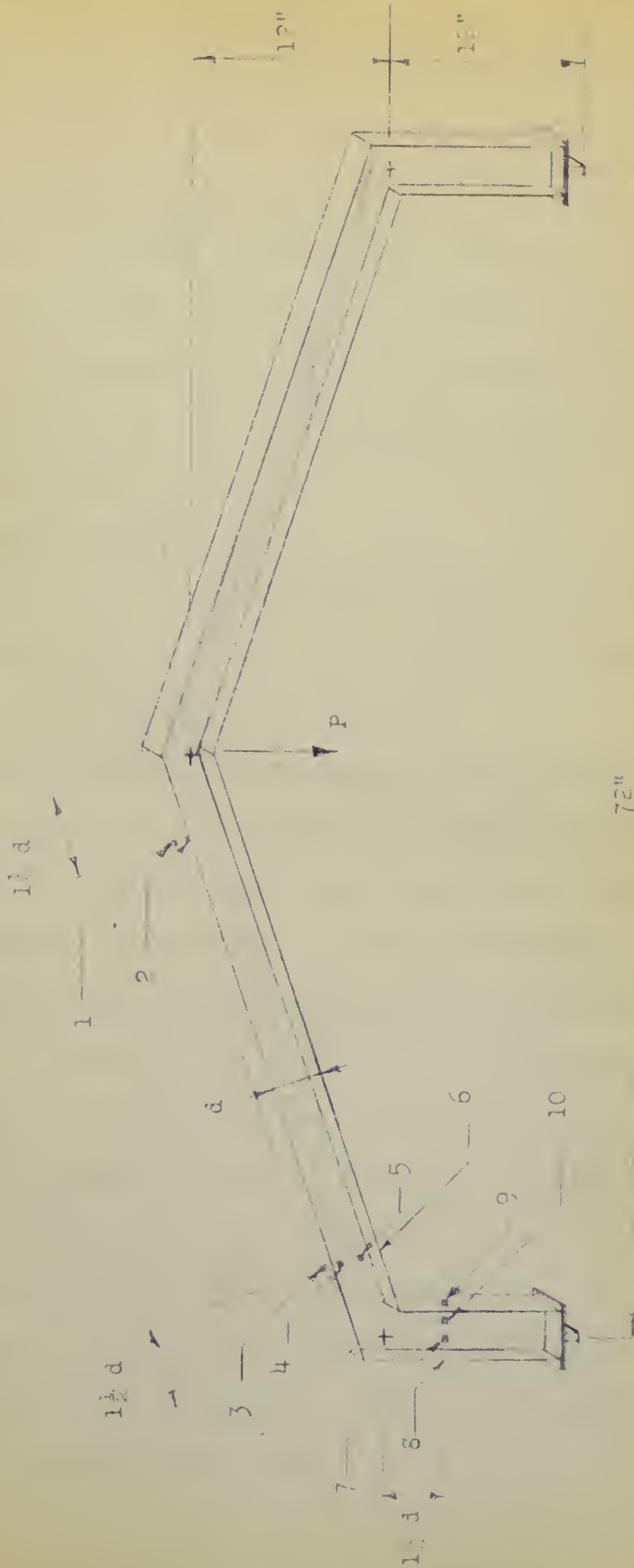
The construction and layout of a rigid frame was determined as the result of a study of all the work done on this subject. A rigid frame is one that is constructed so that it cannot be deformed. The design of building a frame on rigid members may be shown by drawing an example. It is in this section that we discuss how we constructed and tested a rigid frame.

A. *Design*

The task of constructing a rigid frame was undertaken for two reasons. The first, and most important to us, was to investigate the behavior of our specimens and methods in building a frame from their plain rigid beams. Our last test of beams was very successful, however, the beams were all of the same design. Now, in order to be certain that the conditions and methods were rigid, we built the rigid frame as shown in Figure 10. It was as rigid as possible in construction a different shape was used to test, but it was for the reason mentioned above that we made it rigid in design. As explained by the tests run on rigid frames, as mentioned in the introduction, there was still much to be learned, especially about the behavior of the knees. Therefore, by building a rigid frame, we hoped not only to have that our specimens were rigid, but also to measure, observe, and understand of behavior of knees in rigid frames.

B. *Design*

The design of the frame was not completely as



Right Frame Showing Location of Strain Gauges

Figure 20



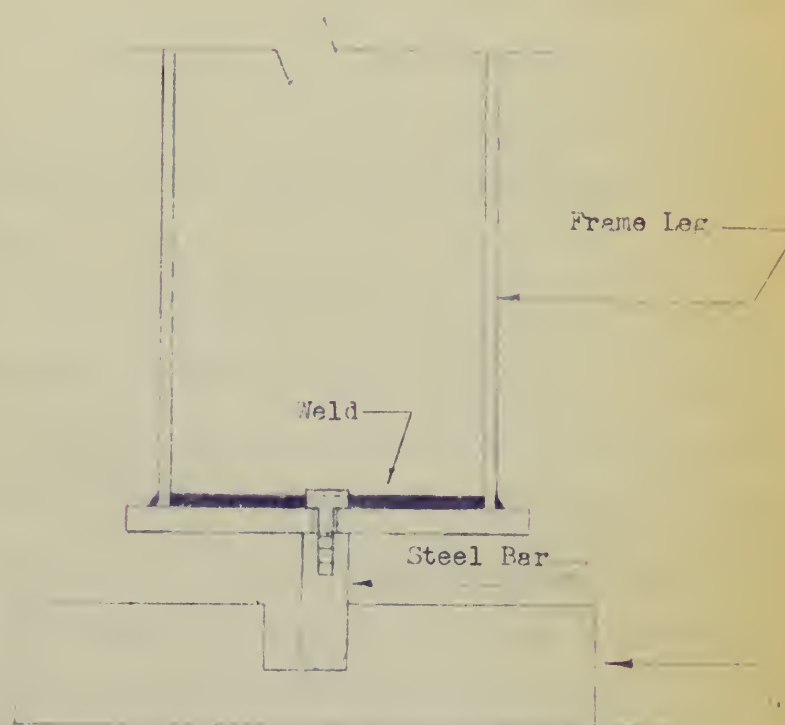
arbitrary one. We attempted to build a frame that, although not an exact copy of a large structure, was similar in most ways to one that might possibly be built. The important feature that influenced our design was the limit we placed on the amount of horizontal shear that we would allow. Although our sample tests indicated that we could go to about 12 lbs./inch, we tried to stay down lower than 8 lbs./inch to be sure that no harm would be done to the welds. Therefore, we designed the frame to give us a maximum deflection with the span being used, along with the lowest possible horizontal shear for any given load.

C. Construction

The rigid frame was constructed using the alladin solder method. It was held and supported as indicated in the discussion under jiggling #3 modified.

The base detail of the legs is indicated in Figure 21. Since there are several ways of testing the frame, it was necessary to develop a base detail that would accommodate any desired method. Therefore, a piece of aluminum plate about 1/4 inch thick was welded to the base of each leg. Two holes were drilled through each plate so that different types of base attachments could be used. The particular attachment we used was a simulated pin on each leg. This was accomplished by bolting a piece of steel bar, rounded on the bottom, to the plate. When the rigid frame was mounted on the horizontal loading frame, the steel bar was inserted into a slotted plate mounted on the loading frame. This slot supported the bar at the bottom and along the sides.

Rigid Frame Base Details



Support attached to horizontal loading frame

Figure 21



Since the length of the frame was 6 ft., it was impractical to cut the flanges and web in one piece. Therefore, it was necessary to devise a method for splicing. It was felt that the best way to insure the maximum strength was to stagger the splices. The location of these splices are shown in Figure 22. In making a splice, the ends of the material should be prepared as shown in Figure 22. This is a recognized method for butt joints as recommended by the Aluminum Company of America. The splices were made using alladin solder, care being used not to apply too much heat, such that the pieces being joined would warp at the splice.

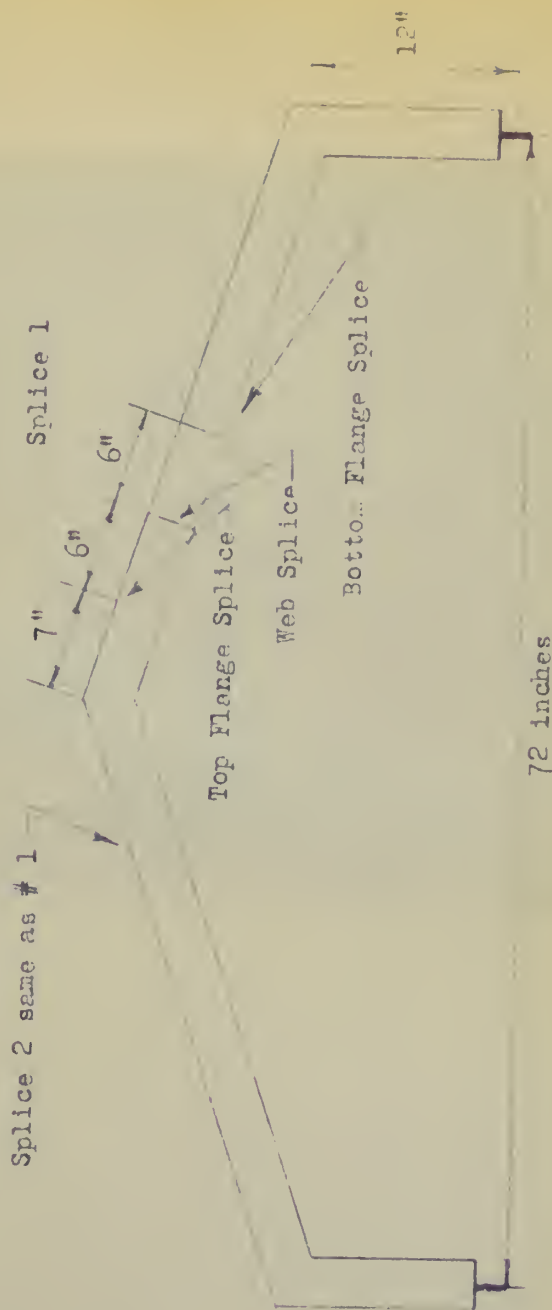
D. Mounting

The frame was mounted on the horizontal loading frame in the same way that beam #11 was mounted. (See Figures 23, 24 and 25.) The four support points used were under the two knees, and one on each side of the load point. Lateral support was provided by two pound weights placed on the frame above the support points. It should be noted here that great care must be taken to insure that the beam is supported correctly at the bases. It is important to have both the bottom of the steel bar and the side of the steel bar bearing along the whole length of the support, or the readings taken will be inaccurate.

The frame was mounted on the horizontal loading
stand in the same way that frame #11 was mounted. (See drawing
55, 56 and 57.) The two horizontal rollers were raised the
two inches, and one on each side of the frame. The
support was divided by the four rollers placed on the frame
above the support rollers. It should be noted that the
case must be taken to insure that the beam is supported
correctly at the base. It is important to have both the
bottom of the steel bar and the side of the steel bar resting
along the whole length of the support, at the readings taken
will be inaccurate.

Notches-3/16"
apart; 1/16"
deep

Splice Detail



Rigid Frame showing location of Splices and Splice Detail.

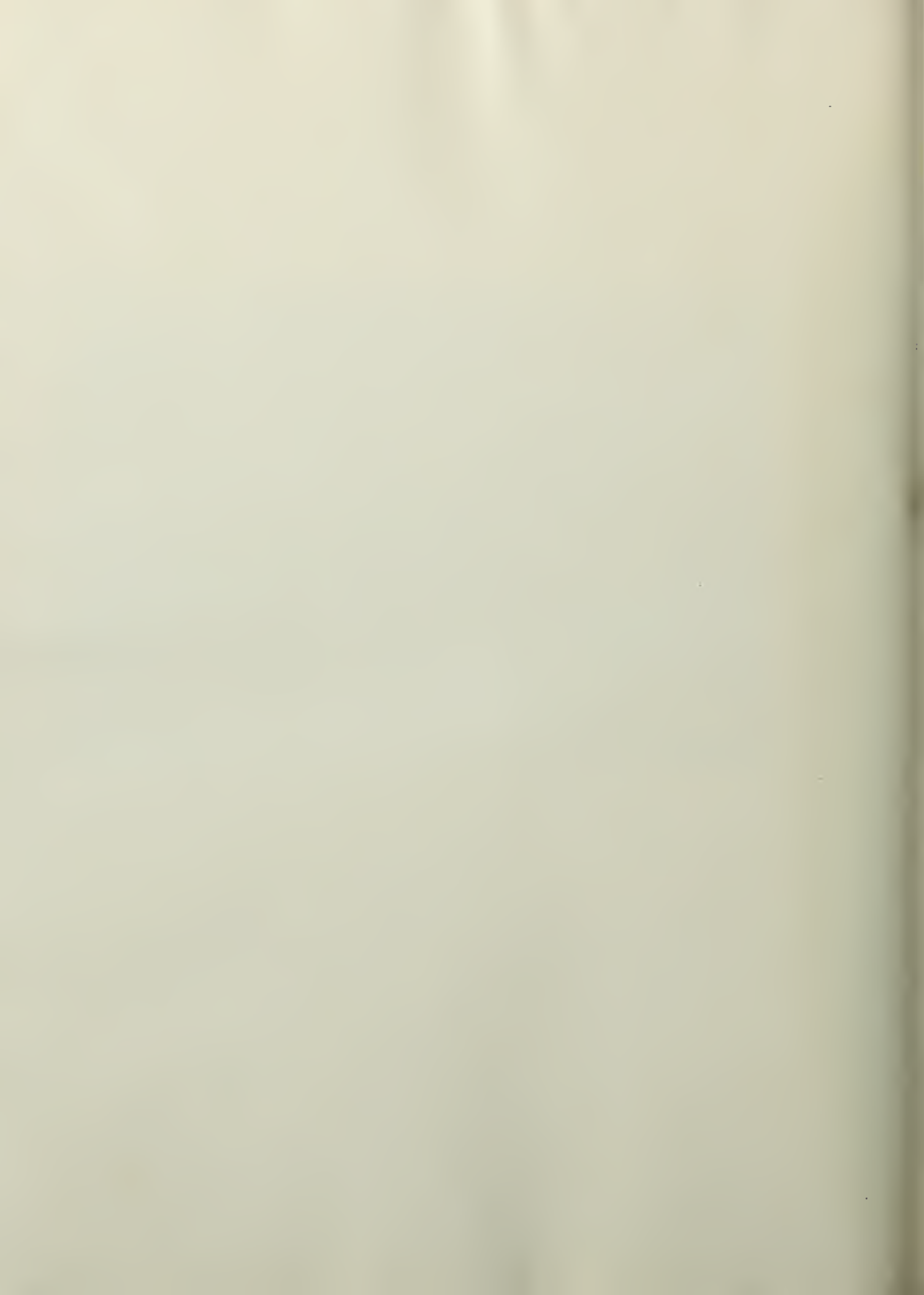
Figure 22



Rigid Frame on Horizontal
Loading Device



Figure 23



Rigid Frame Peak Detail



Figure 24

E. Computations

1. Solution for Deflection of Rigid Frame by the Conjugate Structure Method for a Pinned Base.

See Figure 26

$$(a) \quad D_A = M_{xx} = (20)(341 \text{ P})(2) = 13640 \text{ P}$$

$$(b) \quad d_H = M_{xx} = (72)(8)(2) + (2)(455)(18) + (2)(228)(20) = 26632$$

$$H_A = \frac{13640 \text{ P}}{26632} = .513 \text{ P}$$

$$(c) \quad (60.9 \text{ P})(6.25) + (65.75)(60.9 \text{ P}) + (37 \text{ P})(72) - (51.7 \text{ P})(30.25) - (51.7 \text{ P})(41.75) - 72 \theta_E = 0$$

$$\frac{3333 \text{ P}}{72} = \theta_E = 46.25 \text{ P}$$

$$\frac{EID_B}{2} = (46.25 \text{ P})(12) - (37.0 \text{ P})(4) + (60.9 \text{ P})(2.08) - (51.7 \text{ P})(8.16) = 111.8 \text{ P}$$

$$D_D = D_B = \frac{(2)(111.8)}{(10^7)(.4)} = .0000559 \text{ P}$$

$$EID_C = (46.25 \text{ P})(36) + (51.7 \text{ P})(5.75) - (60.9 \text{ P})(29.75) - (37 \text{ P})(36) = 1182 \text{ P}$$

$$D_C = \frac{1182 \text{ P}}{(10^7)(.4)} = .000296 \text{ P}$$

Computer Program

1. Solution for location of rigid frame by the
Conjugate Beam Method for a fixed base.

See Figure 20

$$(a) \quad O_A = M_A = (50)(5)(1) = 2500 \text{ ft}$$

$$(b) \quad O_B = M_B = (70)(1)(1) + (5)(4)(1) + (5)(2)(1) = 100 \text{ ft}$$

$$M_A = \frac{1000 \text{ ft}}{2000 \text{ ft}} = .5 \text{ ft}$$

$$(c) \quad (50.5 \text{ ft})(1.5) + (50.5 \text{ ft})(1) + (5 \text{ ft})(1) = (51.5 \text{ ft})$$

$$(50.5 \text{ ft}) - (51.5 \text{ ft}) = -1 \text{ ft} = 0$$

$$\frac{1000 \text{ ft}}{2000 \text{ ft}} = .5 \text{ ft} = 0.5 \text{ ft}$$

$$\frac{M_B}{2} = (40.5 \text{ ft})(1) - (20.5 \text{ ft})(1) + (50.5 \text{ ft})(1) = 60 \text{ ft}$$

$$(51.5 \text{ ft})(1.5) = 77.25 \text{ ft}$$

$$M_B = M_C = \frac{(1000 \text{ ft})}{(10 \text{ ft})} = 100 \text{ ft}$$

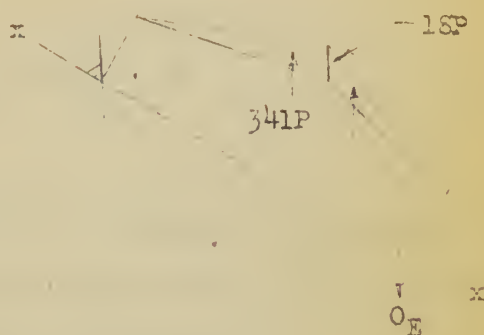
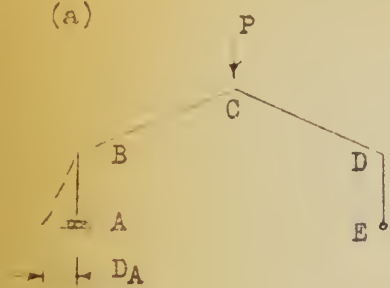
$$M_D = (40.5 \text{ ft})(1) + (51.5 \text{ ft})(1) - (50.5 \text{ ft})(1) = 41 \text{ ft}$$

$$(20 \text{ ft})(1) = 20 \text{ ft}$$

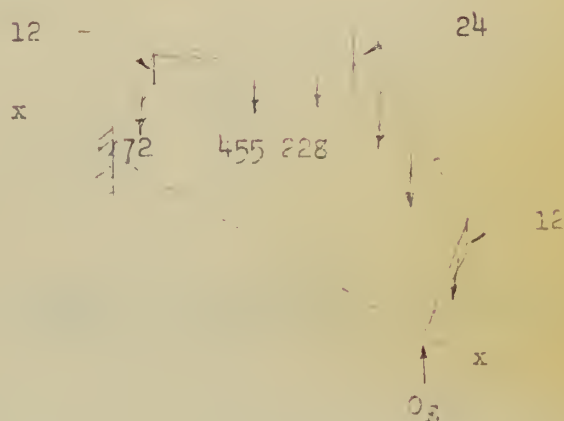
$$M_D = \frac{100 \text{ ft}}{(10 \text{ ft})} = 10 \text{ ft}$$

Diagram for solution of Conjugate Structure

(a)



(b)



(c)

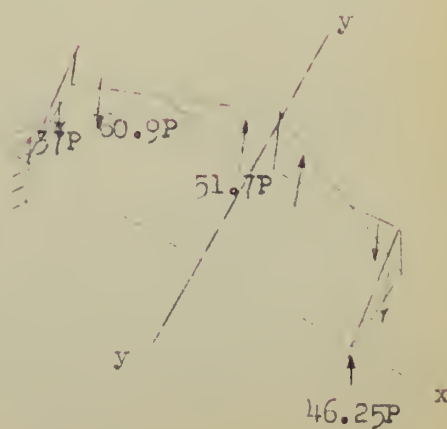
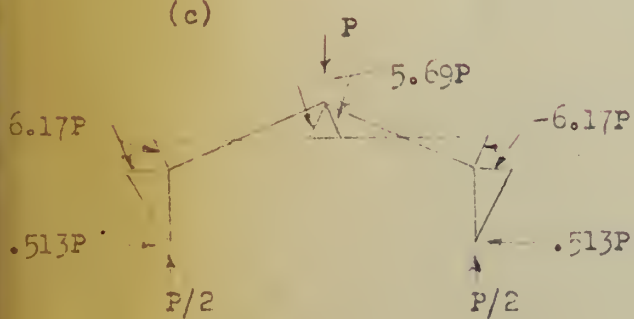


Figure 26

2. Check Solution for Deflections of Rigid Frame
by Integration Using the Method of Virtual Work

$$EID_c = \int M m dx$$

$$EID_c = \int_0^{12} (.513 Px)(.513 x) dx$$

$$+ \int_0^{37.93} \left[(.513 P)(12 + x \sin a) - \frac{P}{2} (x \cos a) \right] \left[(.513)(12 + x \sin a) - .5 (x \cos a) \right] dx$$

$$= .264 P \int_0^{12} x^2 dx + \int_0^{37.93} (38.1 P - 3.85 P x + .0974 Px^2) dx$$

$$= 152 P + 1441 P - 2760 P + 1765 P$$

$$= 598 P$$

$$D_c = 2 \left(\frac{598 P}{EI} \right) = 2 \frac{(598 P)}{(10^7)(.4)} = .000299 P$$

THESE RESULTS ARE THE SAME AS IN THE CASE OF THE

OF THE RESULTS OF THE CASE OF THE

$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

$$\left[\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) \right] + \left[\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) \right] = \frac{1}{2}$$

$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

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$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

3. Corrections to Deflections Resulting from Movement of Base.

It was noted that the base deflected a slight amount when the structure was loaded; therefore, it was necessary to correct previously computed deflections for this movement. This was accomplished by interpolating between the deflections resulting from a pinned base and a base on rollers to obtain the correct deflections.

- a. Solution for horizontal deflection at E, with E on rollers. (See Figure 27.)

$$D_E = \int \frac{Mm \, dx}{EI}$$

$$\frac{EI \, D_E}{2} = \int_0^{37.93} (P/2)(.949)(x)(12 + .316x) \, dx = 6820 \, P$$

$$D_E = \frac{(2)(6820)(P)}{(.4)(10^7)} = .00341 \, P$$

- b. Solution for vertical deflection at C with E on rollers. (See Figure 27.)

$$D_C = \int \frac{Mm \, dx}{EI}$$

$$\frac{EI \, D_C}{2} = \int_0^{36} .25 \, P \, x^2 \, dx = 3888 \, P$$

$$D_C = \frac{(2)(3888 \, P)}{(.4)(10^7)} = .001944 \, P$$

- c. Sample correction for any load P.

	D_C	D_E
Base pinned	.000296 P	0
Actual Conditions	Z	R
Base on rollers	.001944 P	.00341 P

4. Correction in Deflection Reading from
Movement of Water.
It was noted that the scale deflected a slight
amount when the microscope was focused; therefore, it was
necessary to correct previously computed deflections for
this movement. This was accomplished by interpolating be-
tween the deflection readings from a given base and a
base on rollers to obtain the correct deflection.
a. Solution for horizontal deflection at B,
with B on rollers. (See Figure 27.)

$$D_x = \sqrt{\frac{W L^3}{48 E I}}$$
$$\frac{D_x}{D} = \sqrt{\frac{W L^3}{48 E I} \cdot \frac{1}{(2 \sqrt{2}) (1.414) (18 + .318) D}} = \frac{.37 .67}{.7}$$
$$D_x = \frac{(8110000) (.37)}{(1.414) (10^7)} = .00041 \text{ in.}$$

b. Solution for vertical deflection at C with B
on rollers. (See Figure 27.)

$$D_y = \sqrt{\frac{W L^3}{48 E I}}$$
$$\frac{D_y}{D} = \sqrt{\frac{W L^3}{48 E I} \cdot \frac{1}{.667 \times 2 D}} = \frac{.38}{.7}$$
$$D_y = \frac{(8110000) (.38)}{(1.414) (10^7)} = .00042 \text{ in.}$$

c. Sample correction for any load P.

Base on rollers	Actual deflection	Base pinned	D_y	D_x
.00041 in.	in.	.00042 in.	in.	in.

Diagram for Solution of Deflections by Virtual Work

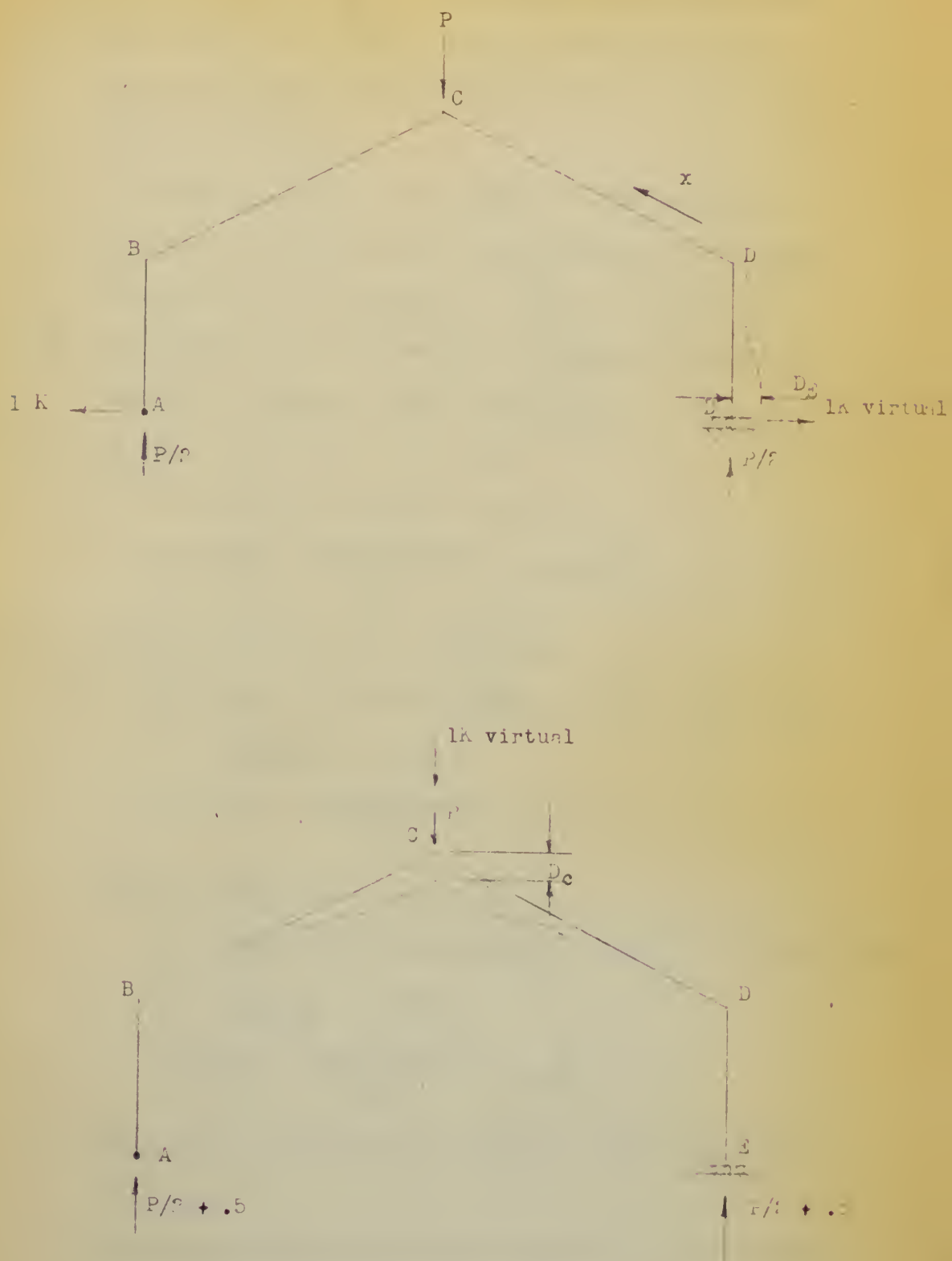


Figure 27

R is the sum of the outward deflections at the bases, as determined by mechanical dials.
Z is the corrected deflection at C, arrived at by interpolation.

The corrected deflection at the knee is arrived at by applying the movement of the base directly to the computed value at the knee.

4. Computations for stresses at various sections along the frame. (See Figure 20.)

On the leg, 1.5 d from knee:

$$M = (.513 P)(8.30) = 4.27 P$$

$$f = \frac{Mc}{I} = \frac{(4.27 P)(c)}{.40} = 10.66 P c$$

On the girder, 1.5 d from knee

$$M = .513 P \left[(3.75) \left(\frac{12}{37.93} \right) + 12 \right] - \left(\frac{P}{2} \right) (3.75) \left(\frac{36}{37.93} \right) = 4.99 P$$

$$f = \frac{Mc}{I} = \frac{(4.99 P)(c)}{.40} = 12.5 P c$$

On the girder 1.5 d from C:

$$M = (.513 P) \left[(34.55) \left(\frac{12}{37.93} \right) + 12 \right] - (P/2)(34.55) \left(\frac{36}{37.93} \right) = 4.60 P$$

$$f = \frac{Mc}{I} = \frac{(4.60 P)(c)}{.40} = 11.5 P c$$

5. Correction to stresses resulting from movement of base.

Due to the movement of the base it was necessary to apply a correction to the stresses computed in section 4

It is the sum of the outward deflections at the base, as determined by numerical trials. It is the outward deflection at C, arrived at by integration.

The reversed deflection at the knee is arrived at by applying the movement of the base directly to the horizontal axis at the knee. Comparison for stresses in various sections

Along the frame. (See Figure 52.)

On the left, 1.5 ft from base

$$M = (0.12)(116.50) = 14.17 \text{ ft}$$

$$V = \frac{10}{1} = 10.00 \text{ ft}$$

On the right, 1.5 ft from base

$$M = 0.12 \left[(1.5)(116.50) + 10 \left(\frac{10}{2} \right) \right] = 14.17 \text{ ft}$$

$$V = \frac{10}{1} = 10.00 \text{ ft}$$

On the right, 1.5 ft from top

$$M = 1.5(116.50) + 10 \left(\frac{10}{2} \right) = 14.17 \text{ ft}$$

$$V = \frac{10}{1} = 10.00 \text{ ft}$$

Comparison of stresses resulting from movement

of base.

Due to the movement of the base it was necessary

to apply a correction to the stresses computed in section A

above. The manner in which the stresses were corrected is shown below.

	H_E	D_E
Base Pinned	.513 P	0
Actual Conditions	Y	Q
Base on Rollers	0	.00341 P

Q is the average of the outward deflection at the two bases.

Y is the corrected value of horizontal reaction (H_E) due to movement of the bases. The corrected stresses are obtained by multiplying the computed values, as obtained in section 4 above, by $\frac{Y}{.513 P}$.

[illegible]

shown below.

6	4	313.	Base lined
4	1		Local Committee
4	1		Base on Police

by multiplying the computed values, as obtained in section 4, moment of the bars. The corrected values are obtained by multiplying the corrected value of horizontal reaction (4g) due to \bar{X} is the average of the outward deflection at the two bases.

• 70 rods
N.E. 1/4

F. Load Tests and Results

1. Deflections

a. Deflections at C

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Corr. Def. (Z)</u>	<u>% Diff.</u>
	<u>Zero</u>	<u>Loaded</u>			
10	.1085	.11225	.00375	.00339	10.6
20	.1095	.1166	.0071	.00683	3.2
30	.1095	.1212	.0117	.01036	12.9
40	.1090	.1250	.0160	.01443	9.8
50	.1090	.1290	.0200	.01796	11.3

b. Deflection at B or D

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Corr. Def.</u>	<u>% Diff.</u>
	<u>Zero</u>	<u>Loaded</u>			
10	.04085	.04185	.0010	.000609	64.0
20	.0415	.0434	.0019	.00192	1.0
30	.0549	.0579	.0030	.00288	4.2
40	.0483	.0528	.0045	.00464	3.0
50	.0537	.0478	.0059	.0060	1.7

c. Sum of the Deflections of the two bases

<u>Load</u>	<u>Deflection</u>
10	.0009
20	.0020
30	.0031
40	.0054
50	.0066

Table 1. - Summary of Test Results

1. Test Results

2. Test Results

Test No.	Test Date	Test Result	Test Result	Test Result	Test Result
101	10/1/50	100%	100%	100%	100%
102	10/2/50	100%	100%	100%	100%
103	10/3/50	100%	100%	100%	100%
104	10/4/50	100%	100%	100%	100%
105	10/5/50	100%	100%	100%	100%

3. Test Results

Test No.	Test Date	Test Result	Test Result	Test Result	Test Result
106	10/6/50	100%	100%	100%	100%
107	10/7/50	100%	100%	100%	100%
108	10/8/50	100%	100%	100%	100%
109	10/9/50	100%	100%	100%	100%
110	10/10/50	100%	100%	100%	100%

4. Summary of Test Results of the Two Series

Test No.	Test Result
101	100%
102	100%
103	100%
104	100%
105	100%

2. Stresses

P = 10 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1202	0770	0220	1699	2000	1340	1069	1981
Loaded	0206	1865	1217	0778	0216	1686	2003	1352	1060	1977
e	14	13	15	8	4	13	3	12	9	4
Act. f	140	130	150	80	40	130	30	120	90	40
Corr. f	140	140	151.5	67.7	67.7	151.5	51.2	130	130	59
% Diff.	0	7.1	1.0	18.1	40.7	14.1	41.6	7.7	32.5	32.2

P = 20 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1202	0770	0220	1699	2000	1340	1069	1981
Loaded	0193	1850	1230	0783	0209	1673	2008	1362	1051	1971
e	27	28	28	13	11	26	8	22	18	10
Act. f	270	280	280	130	110	260	80	220	180	100
Corr. f	280	280	304	136	136	304	102	260	260	118
% Diff.	3.5	0	7.8	4.4	19.1	14.5	21.6	18.2	30.8	15.2

P = 30 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1198	0770	0220	1698	1998	1330	1072	1981
Loaded	0178	1836	1241	0788	0200	1660	2011	1373	1041	1965
e	42	42	43	18	20	38	13	43	31	16
Act. f	420	420	430	180	200	380	130	430	310	160
Corr. f	419	419	457	204	204	457	155	389	389	178
% Diff.	.2	.2	5.9	11.7	1.9	16.9	16.1	10.5	20.3	10.1

P = 40 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0219	1874	1198	0768	0220	1698	1998	1330	1072	1981
Loaded	0161	1821	1251	0791	0193	1649	2015	1381	1033	1960
e	58	53	53	23	27	49	17	51	39	21
Act. f	580	530	530	230	270	490	170	510	390	210
Corr. f	557	557	604	270	270	604	205	517	517	236
% Diff.	4.1	4.1	12.2	14.8	0	18.8	17.0	1.3	24.6	11.0

P = 50 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0219	1874	1198	0768	0220	1698	1998	1330	1072	1981
Loaded	0149	1806	1263	0796	0186	1634	2018	1393	1023	1953
e	70	68	65	28	34	64	20	63	49	28
Act. f	700	680	650	280	340	640	200	630	490	280
Corr. f	696	696	756	337	337	756	256	645	645	295
% Diff.	.6	2.3	14.0	16.9	.9	15.3	21.3	2.3	24.9	18.6

3. Conclusions

In the process of testing our beams and the rigid frame on the horizontal loading device, we came across a method of loading that eliminates the possibility of the beam twisting due to the eccentricity of the load.

It was necessary to have some method for centering the load since any twisting causes errors in the values of the stresses. The way this was done for the rigid frame is indicated below.

Gages #1 and #2 were mounted, one on each side of the loaded flange near the load point. The loading yoke was then adjusted so that the stresses indicated by these gages were as near equal as possible. When these stresses are equal, the yoke is applying the load correctly to the frame. By using this method, the percentage error for all strain gages was less.

Although the differences between the observed and calculated stresses and deflections for the rigid frame were greater than for beam number 11, they were still considered satisfactory. There were many more sources of error in the construction of a rigid frame. Possibilities for inaccuracies were introduced in the fabrication of other than a straight model, in splicing, and in the construction of the base detail. The base detail, in particular, introduced complications. It should be noted that corrections to both the deflections and stresses had to be made to compensate for horizontal movement of the base, which was originally designed for no movement.

[illegible][illegible]

In general, the authors felt that the results indicate the overall soundness of the techniques and methods used.

In January, the report said the results

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VI. Discussion

In writing this thesis, we have attempted to break it down into sections so that each division was a subject in itself. This method allowed us to gather the results from each test and to present them along with the material from which they were deduced. Therefore, it will not be necessary for us to mention the results we have already listed. There are, however, several items of a general nature that are of interest as an overall result of each method attempted.

The welding of aluminum using eutecrod was very difficult. It took weeks of practice for us to become proficient enough to weld the aluminum without fear of completely melting the parent material. Also, the heating of the aluminum to a high temperature annealed it so that a large furnace for heat treatment would be required to temper it. We, therefore, conclude that eutecrod welding is impractical for building models in the laboratory.

From the tests we have run, we feel that the construction of accurate models by soldering is practical. It is definitely possible to construct models and to obtain reasonable results with close accuracy. The major fault with soldering is that low loads must be applied in order to stay within the required limits of horizontal shear. Although the models constructed were near perfect, the allowable stress was never developed, and it was, therefore, impossible to ascertain the effects of high stresses.

[illegible]

The results from the tests run on the beams constructed with steel and silver solder were not satisfactory. The beams obtained from the furnace method seemed absolutely perfect. We have no explanation for the poor results obtained, other than perhaps that the joint was not perfectly soldered although it appeared to be so. In view of the high loads the horizontal loading frame is capable of handling, we feel that the investigation of steel should be continued. It is definitely the feeling of the authors that a small amount of work with the steel method would produce very satisfying results.

THE RESULTS FROM THE TESTS ON THE SAME COMPOUNDS

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VII. Conclusions

A. Aluminum soldering, using alladin rod to form the joint between model components, which are assembled in accordance with jigging method number 3 modified, is suitable for model construction.

B. Aluminum welding as a method of joining model components is not feasible because of the amount of time required to become proficient in welding, and because of the uncontrollable warping and distortion attendant with it.

C. Furnace brazing aluminum, using eutecrod as the filler material, is not possible.

D. With further work and development, a method of silver soldering steel to fabricate models suitable for high stresses could be evolved.

1. Aluminum chloride, AlCl_3 , was prepared by the reaction of aluminum metal with hydrochloric acid. The reaction was carried out in a round-bottomed flask equipped with a magnetic stirrer and a reflux condenser. The flask was cooled in an ice-water bath. The aluminum metal was added in small pieces to the acid, and the reaction mixture was stirred until the metal had completely dissolved. The solution was then concentrated under reduced pressure to give a white solid.

Q. How many times did you see the defendant in the
company of the woman who was with him at the time
of the shooting?



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J64 The development of a
laboratory technique for
model construction.

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